INSECTS AND DISEASE OF MAN

CARROLL FOX

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BY

CARROLL FOX, M.D.

SURGEON, U. S. PUBLIC HEALTH SERVICE; LECTURER ON MEDICAL ENTOMOLOGY TO THE CLASS OF STUDENT OFFICERS, HYGIENIC LABORATORY, WASHINGTON, D. C.; FELLOW OF THE AMERICAN PUBLIC HEALTH ASSOCIATION, MEMBER OF THE AMERICAN STATISTICAL ASSOCIATION, THE PACIFIC COAST ENTOMOLOGICAL SOCIETY, THE AMERICAN MEDICAL ASSOCIATION; ONE TIME ASSISTANT DIRECTOR OF HEALTH, BUREAU OF HEALTH, PHILIPPINE ISLANDS, AND ASSOCIATE PROFESSOR OF HYGIENE, MEDICAL SCHOOL, UNIVERSITY OF THE PHILIPPINES

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PREFACE

In this book I have attempted to gather together in a concise and practical way, the information necessary for a student taking up the study of medical entomology, or for the health officer working in the field of preventable diseases transmitted by anthropods.

The subject is large and any one of its branches is a specialty in itself. Much of the literature appears in the form of separate articles in serial publications, or as, monographs, bulletins, etc. Therefore it is hoped that this book which aims to give only the essentials for public health practice may be found to be helpful and worth while. As the time of the student is limited, and this is particularly true of the student officers forming my classes, I have not burdened the text (for which no claim to originality is made) with references; therefore, mention must be made here of my indebtedness to the writings of those who have devoted their time to the subject, and particularly G. H. F. Nuttall, Cecil Warburton, Nathan Banks, H. E. Ewing, C. W. Stiles, N. Charles Rothschild, Karl Jordan, Carl F. Baker, Ll. Lloyd, V. L. Kellogg, G. F. Farris, Edward R. Stitt, Victor B. Vaughan, W. B. Herms, Herbert Osborn, G. Enderlein. L. O. Howard, H. G. Dyar, F. Knab, J. M. Aldrich, R. C. Shannon, W. H. W. Komp, C. S. Ludlow, Bruce Mayne, J. A. LePrince, J. W. Folsom, J. H. Comstock, E. T. Cresson, Jr. and W. R. Walton; to W. S. Patton and F. W. Cragg and their valuable "Text Book of Medical Entomology;" to Aldo Castellani and Albert J. Chalmers and to the various authors who have contributed to Byam and Archibald's "Practice of Medicine in the Tropics," as well as to the authors of the various official publications of the Bureau of Entomology, U. S. Department of Agriculture, the U. S. Public Health Service and State Departments of Health.

I am greatly indebted to Doctor Philip P. Calvert, Professor of Zoology in the University of Pennsylvania, to Doctor Henry E. Ewing of the Bureau of Entomology, U. S. Department of Agriculture, and to Professor C. W. Stiles, U. S. Public Health Service for their kindness in reading the manuscript and offering many valuable suggestions: to Surgeon-General Hugh S. Cumming,

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Carroll Fox.

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PART I

MEDICAL ENTOMOLOGY

INSECTS AND DISEASE OF MAN

CHAPTER I

Entomology is that part of Zoology which treats of insects. Medical entomology may be defined as that part of entomology which treats of those insects which are directly or indirectly concerned with the occurrence or spread of diseased conditions in human beings or animals or which serve as pests. It is generally agreed that the term may include acarines or other arthropods which have been implicated in the occurrence or spread of disease.

The Arthropoda.—The Phylum Arthropoda is that great subdivision of the animal kingdom, the members of which are invertebrates having paired, jointed appendages to the segments of the head, thorax and sometimes the abdomen; a ventral nervous system; a dorsal digestive system and an ecto-skeleton. The Phylum is subdivided into the following classes:

Class Insecta (Insects, sometimes spoken of as Hexapoda)
Class Arachnida (Mites, spiders, scorpions)
Class Crustacea (Crabs, lobsters, shrimps, cyclops, sow bug)
Class Myriapoda (Centipedes and millipedes)
Class Protracheata (Peripatus)

CLASS INSECTA

(The Insects)

General Considerations.—The body of an insect is composed of a head, a thorax and an abdomen.

The head is provided with eyes, simple or compound or both, two antennae or feelers, and the mouth parts including the maxillary palpi. The structure of the mouth parts varies depending upon the feeding habits of the insect. They may be masticatory or suctorial and may be adapted to piercing or cutting the skin and sucking blood.

The thorax is divided into three segments, the pro- meso- and meta-thorax. Each segment is divided into two main portions the tergites or nota forming the dorsal part and the sternites the ventral part. The lateral surfaces are known as the pleura. From both sides of each sternite there arises a leg, making three pairs of legs in all. Each leg is composed of a coxa, trochanter, femur, tibia and tarsus. From each side of the meso- and metathorax there arises a wing, making two pairs of wings in all. This however is not true of all members of the Class for in the Order Diptera there is but one pair of well developed wings the second or hind pair being rudimentary; in some of the Hemiptera there are merely vestiges of one pair of wings only, while in the Orders Siphonaptera and Anoplura wings are entirely wanting.

There is no osseous system. The hard chitinous integument, the ecto-skeleton, which invests the body of the insect serves not only as a protecting covering to the soft parts but as an attachment for muscles, as well as to maintain rigidity.

There is no vascular system. The blood, which is colorless, circulates in the body cavity and is kept in circulation by passing through a thin-walled pulsating aorta located in the extreme dorsal part of the abdomen and thorax.

There is no lung or gill. Air is taken in through stigmatic openings located on the sides of the thorax and abdomen. It is carried to the most remote parts of the body by a system of branching tracheae which have their origin at the stigmatic openings.

The central nervous system is represented by a chain of ganglia running close to the ventral wall, from the head through the thorax and into the abdomen. The first or largest ganglion, the brain, is located in the head and is pierced by the oesophagus.

The special senses are well developed.

The kidneys are represented by the Malpighian tubules which empty into the intestines.

The digestive system, the salivary glands and the reproductive organs are well developed. The salivary glands and their ducts have no connection with the alimentary tract, other than the buccal cavity.

The number of segments of the abdomen varies. There are normally ten, the terminal segments being modified to form the accessory organs of generation. Each segment is composed of a tergite dorsally and a sternite ventrally. They are connected to

each other by a soft membrane. The membrane connecting the tergite with the sternite contains the opening of the trachea and is called the pleural membrane.

The body of an insect is furnished with setae (hairs and bristles), and at times with spines and perhaps with spurs.

Depending on the species an insect in its life cycle may undergo a complete or an incomplete metamorphosis. The former requires four stages namely, egg, larva, pupa and imago or adult. Growth occurs in the larval stage, the larva shedding its old skin as it increases in size, a new one having formed to take the place of the old. The larva is active and voracious. When fully grown it turns into a pupa in which stage the insect ceases to eat and is usually quiescent but may be active as in the case of mosquitoes. It is in the pupal stage that the wonderful changes take place which transform the lowly wormlike larva into the fully developed, highly organized adult insect.

The incomplete metamorphosis is somewhat different. The young emerge from the egg looking not unlike the adult except in size, color and hardness. They eat the same food as the adult. These immature forms grow by successive moultings similar to the larval stage of the complete metamorphosis. The sexes are not differentiated until the final moult which results in a fully formed and fully grown insect. These immature moulting forms correspond to the larval and pupal stages of the complete metamorphosis.

There are a number of Orders in the Class Insecta which are of no interest in preventive medicine even though economically they may be of great importance because of their destructive influence on growing vegetation. If these are excepted together with those insects which can sting but can not bite and those which have habits not endangering the health of man, it is found that the insects which are concerned in the present study fall within five Orders, namely the Diptera (flies and mosquitoes), the Siphonaptera (fleas), the Anoplura (lice), the Hemiptera (bugs) and, not so important, the Orthoptera (roaches).

CHAPTER II

THE DIPTERA

(The Flies and Mosquitoes)

Description.—Insects of this Order are characterized by having two well developed transparent wings, with a second pair of rudimentary wings or halteres, the so called balancers. The mouth parts are well developed and adapted to piercing and sucking, or to suction only. The mesonotum forms a large part of the thorax. Its dorsal aspect forms a plane surface but it may be interrupted by a transverse suture, or by a marked V-shaped suture as in the Tipulidae (crane flies). There are two compound eyes and in some species ocelli or simple eyes are also present. The metamorphosis is complete, that is, the insect passes through the four stages of development—egg, larva, pupa and adult insect. In some Diptera the egg is not laid but develops in the body of the female which then gives birth to a larva.

Like all insects the body is divided into a head, thorax and abdomen.

The Head.—In certain large groups of the Diptera there is to be seen an anterior depressed area on the head known as the lunula which is bounded by an arched suture, the ptilinal suture, passing over the base of the antennae. This suture represents the invaginated ptilinum or the vesicle with which the fully developed insect breaks its way out of the pupal covering. The antennae may be many or few jointed, and may have on the third joint a bristled appendage called the arista, or a style. The mouth parts consist of a labrum (with which may be combined an epipharynx) mandibles, maxillae, hypopharynx and labium. These however differ greatly in the different families.

The Thorax.—The thorax is divided into the prothorax, the mesothorax and the metathorax. From each side of the mesothorax between the sternite and tergite dorsally of the epimerum there arises a wing and farther posteriorly may be seen the smaller, club shaped halteres arising one on each side of the metathorax. The

disposition of the veins in the wings is of importance in classifying the members of the Diptera as are also the presence or absence of setae (scales, hairs and bristles). The *discal cell*, when present, is a good land-mark from which to locate other wing characters. It is bounded by the 4th. and 5th. longitudinal veins. A membranous prolongation backwards from beneath the base of the wing and known as the *squama* may be present and may be so large as to conceal the halteres.

Legs. The tarsus consists of *five segments*, the last segment ending in two *claws* and often two *pulvilli* which when developed are membranous pads. Between the *pulvilli* may be present what is called the *empodium*, which may be absent, bristle-like or tapering, or may be pulvilliform (membranous like the pulvilli).

Abdomen.—The abdomen is normally divided into ten segments, the terminal segments being modified in the different sexes.

CLASSIFICATION OF THE DIPTERA

Diptera may be classified into certain large groups according to the characters of the larva, the pupa, and the antennae, as follows:

First, they are divided into two great Suborders depending upon the means of escape of the adult from the pupal covering. If by a dorsal T-shaped slit, they are placed in the Suborder Orthorrhapha. The larvae of this Suborder have a distinct head. If the adult escapes by a circular opening in the head end of the pupal case it is placed in the Suborder Cyclorrhapha. Larvae of this Suborder are without a distinct head.

The Suborder Orthorrhapha is then subdivided into two Sections, one, Brachycera or Orthorrhaphous Diptera with short antennae, and one, Nematocera or Orthorrhaphous Diptera with long antennae. The former are then further divided into those having two well defined pulvilli and a pulvilliform empodium, the Brachycera homodactyla, and those which if they have two pulvilli and an empodium, the latter is bristle-like and does not resemble a pulvillus, the Brachycera heterodactyla.

The Suborder Cyclorrhapha is divided into three sections namely, Aschiza, Schizophora and Pupipara. The Aschiza contains no species known to bite man. The Schizophora contains the true flies. This Section is subdivided into two tribes depending upon whether the squamae are small or rudimentary, Muscoidea acalyp-

tratae, or whether they are large, Muscoidea calyptratae. The third Section is known as Pupipara because the fully developed larvae are passed directly from the body of the adult female. It must be kept in mind that certain flies of the other groups are also larviparous.

Key to Some of the Families in the Order Diptera

1. Abdomen indistinctly segmented, sac-like; integument leathery; body flattened dorso-ventrally; wings present, absent or vestigial (Page 111). Pupipara
   Abdomen distinctly segmented; wings rarely absent 2
2. Antenna long and composed of more than six segments, all but the first two similar; arista absent; discal cell usually absent (present in Tipulidae and Rhyphidae); anal cell widely open at margin
   Suborder Orthorrhapha, Section Nematocera 3
   Antenna short and composed of three (or four) segments, differing from one another, the third joint simple, annulated or pseudo-segmented, with or without style or arista; discal cell rarely absent; anal cell closed or narrowed at margin, rarely absent 8
3. Wing venation much reduced, fewer than nine veins reach margin of wing 4
   Nine or more veins reach margin of wing (Fig. 4) 5
4. Antenna shorter than thorax, rather stout, never plumose and composed of ten or eleven closely united segments; abdomen in both sexes with a conspicuous flap-like scale at base of dorsal surface which is detached posteriorly and fringed with long hairs; rather stout short insect (Page 50) Simuliidae
   Antenna longer and slender, usually feathery in the males; abdomen without flap-like scales at anterior corners (Page 50) .... Chironomidae
5. All cross veins placed towards base of wing (before the middle) and body very hairy or scaley; minute moth-like flies (Page 51) .... Psychodidae
   One or more cross veins at or beyond middle of wing; unlike minute moths in appearance 6
6. Ocelli present .... Rhyphidae
   Ocelli absent 7
7. Mesonotum with a V-shaped suture; usually a discal cell and two anal veins present .... Tipulidae
   Mesonotum without suture; wings never with two anal veins or a discal cell; veins clothed with scales; posterior margin of wings with a close fringe of scales (Page 10) .... Culicidae
8. Third longitudinal vein usually forked; empodium often pulvilliform; arista or style present or absent, when present usually terminal; antenna usually prominent, projecting; lunula and ptilinal suture absent 9
   Third longitudinal vein never forked; empodium never pulvilliform; arista usually dorsal, rarely absent; antenna pendulous; lunula or lunula and ptilinal suture present 22
9. Third longitudinal vein forked 10

Third longitudinal vein not forked 20

10. Discal cell small, little if any longer than broad; subcostal and 1st., 2nd., and 3rd. longitudinal veins crowded together near costal border. Stratiomyiidae

Discal cell distinctly longer than broad; veins not crowded together as above.... 11

11. Third segment of antenna annulated, without style or arista.... ... 12

Third segment of antenna simple, with or without style or arista 14

12. Squamae large; third segment of antenna marked with from four to eight annuli or rings; five posterior cells; forks of third vein inclose apex of wing (Fig. 22) (Page 53)... . .. .Tabanidae

Squamae small.... 13

13. Fourth posterior cell closed.. . ...Xylomyiidae

Fourth posterior cell open.......... ....Xylophagidae Coenomyiidae

14. Vertex hollowed out between the eyes...............................15

Vertex plane or convex......... 16

15. Antenna four segmented more or less clubbed at end; proboscis fleshy at tip; 1st., 2nd., and 3rd. longitudinal veins coalescing before the apex of wing; 4th. longitudinal vein terminating before apex of wing Mydaidae

Antenna three segmented with or without terminal style; proboscis pointed at tip; longitudinal veins not as above........................Asilidae

16. Squamae very large, head very small, thorax and abdomen large; forks of 3 rd. longitudinal vein ending before apex of wing..........Acroceridae

Squamae small or vestigial...17

17. Forking of 3rd. longitudinal vein tending to inclose apex of wing, at least the posterior branch of the fork ending behind the apex of wing......18

Both branches of third longitudinal vein ending before the apex of wing; antenna without style or arista; three posterior cells.......Scenopinidae

18. Empodium pulvilliform; five posterior cells usually open; antenna with style or arista; abdomen tapering...........................Leptidae

Empodium rudimentary or absent....................................19

19. With five posterior cells, the fourth narrowly open or closed; anal cell usually closed; style usually present; abdomen tapering......Therevidae

With four posterior cells (rarely 3 or 5); 1st posterior cell narrowly open or closed; anal cell narrowly open or closed; antennae with or without style; abdomen not tapering.................. .. ..Bombyliidae

20. Veins near costal border strong, those extending across wing weak; antenna apparently composed of one globular segment with a three segmented arista; small, black, hunch-backed flies.......................Phoridae

Veins not as above...21

21. Discal and basal cells not separated by a vein; anal cell vestigial; usually bright metallic blue or green flies.................... . Dolicopodidae

Discal and basal cell distinct; anal cell present but small ....Empidae

22. Lunula present, ptilinal suture absent; third segment of antenna simple; arista either terminal or dorsal.

Suborder Cyclorrhapha Section Aschiza... 24

Ptilinal suture well defined; lunula present; antenna lie in separate grooves and are composed of three simple segments; arista well developed, dorsal; anal cell usually present, small; three posterior cells.

Suborder Cyclorrhapha, Section Schizophora....23

23. Squamae large; thorax with complete transverse suture; subcostal vein present well developed..................Muscoidea Calyptratae....25

Squamae small or rudimentary; thorax without complete transverse suture; subcostal vein often small or rudimentary.

Muscoidea Acalyptratae....31

24. Wings with a spurious longitudinal vein (a thickening of the membrane) between the 3rd. and 4th. longitudinal veins; arista usually dorsal occasionally with terminal style; no antennal grooves (Page 60)...Syrphidae

Without spurious vein; head very large and composed almost entirely of eyes; arista dorsal....................................Pipunculidae

25. Mouth parts greatly reduced, almost absent, mouth opening small; antenna small more or less hidden in round pits; body very hairy (Page 75).

Oestridae

Mouth parts well developed; adapted to piercing and sucking or to suction only; antennae well developed. not hidden..........................26

26. Hypopleural bristles absent or only some fine hairs present........... .27

Hypopleural bristles well developed............ 28

27. First posterior cell more or less narrowed; outer portion of 4th. longitudinal vein more or less strongly angled or curved towards third vein, at least slightly but noticeably curved at apical end (Page 79).. Muscidae

First posterior cell widely open; 4th. longitudinal vein not angled or curved towards third vein, apical end straight (Page 107)........Anthomyiidae

28. Post scutellum very pronounced i.e. metanotum with a double convexity..29

Post scutellum rudimentary or absent i.e. metanotum with a single convexity..30

29. Arista bare...Tachinidae

Arista plumose..Dexiidae

30. Arista hairy or pubescent above and below for half or a little more than half its length, outer half bare (Page 90)................Sarcophagidae

Arista hairy for its entire length or nearly so; body often metallic blueish or greenish (Page 97)..... ....Calliphoridae

31. Subcostal vein present; 1st. longitudinal vein ends near or beyond the middle of the wing...32

Subcostal vein absent, vestigial or incomplete; 1st. longitudinal vein ends before the middle of the wing; eye not stalked...............   .34

32. Oral vibrissae present, distinct..............................   .33

Vibrissae absent; lower fronto-orbital bristles absent; wings marked with dark spots or bands...Ortalidae

33. With a break or scar in the costa near the termination of the subcostal vein; frontals convergent fairly large yellow or brown flies...... Scatophagidae

Without a break or scar in the costa; front not bristly near the antenna; palpi vestigial; small, slender black flies with elongated, cylindrical abdomen..................... ....Sepsidae

34. First segment of hind tarsus thickened and swoolen shorter than second segment . . . . Borboridae
First segment of hind tarsus not thickened, longer than second segment . . 35
35. Discal and posterior basal cells confluent 36
Discal and posterior basal cells separate 37
36. Anal cell absent; vibrissae rarely present; small bare, light colored flies (Page 61) . . . . Oscinidae
Anal cell present small; oral vibrissae present; arista long plumose (Page 61) . . . . Drosophilidae
37. Wings marked with dark spots or bands; vibrissae absent; fronto-orbitals numerous extending to antenna; anal cell often with a narrow lobe. Trypetidae
Wings not marked; vibrissae present; arista long, plumose; anal cell not lobed . . . . Drosophilidae

CHAPTER III

SUBORDER ORTHORRHAPHA

SECTION NEMATOCERA

Family Culicidae

(The Mosquitoes)

Mosquitoes can be distinguished from all other Diptera by the wing venation and the presence of scales on the wings and head and generally on the thorax and abdomen. These scales are flat scales which may be broad or very narrow. They may be forked, lanceolate, curved etc. and they may stand upright or lie flat (appressed).

Adult. Anatomy (Fig. 1). **The Head.**—There are two compound eyes, the area between them being known as the frons anteriorly, the vertex above and the occiput posteriorly. Projecting over the attachment of the proboscis is a bulbous prolongation of the frons known as the clypeus.

The proboscis, (Fig. 2) which is straight in all forms of mosquitoes of interest to medical entomologists, consists of,—

1. A fleshy, scaled, grooved organ known as the *labium*. It terminates in two short hinged processes known as the *labellae*. At the end of the labium, between the labellae, is a thin membrane called *Dutton's membrane*. In the groove of the labium and protected by it, rests the actual piercing organs,—the stilette bundle, which is made up of,

2. *The labrum-epipharynx*, grooved on its under surface,

3. The *hypopharynx*, which coming in contact with the labrum-epipharynx closes its groove and forms a tube through which the blood is sucked. In the hypopharynx is a channel, the salivary canal down which the salivary juice passes and, when present, the sporozoites of Malaria. There are also

4. A pair of mandibles and

5. A pair of maxillae.

The mandibles lie on either side of the hypopharynx above and the maxillae lie on either side of the hypopharynx below. The maxillae and mandibles are serrated. In the act of biting they move up and

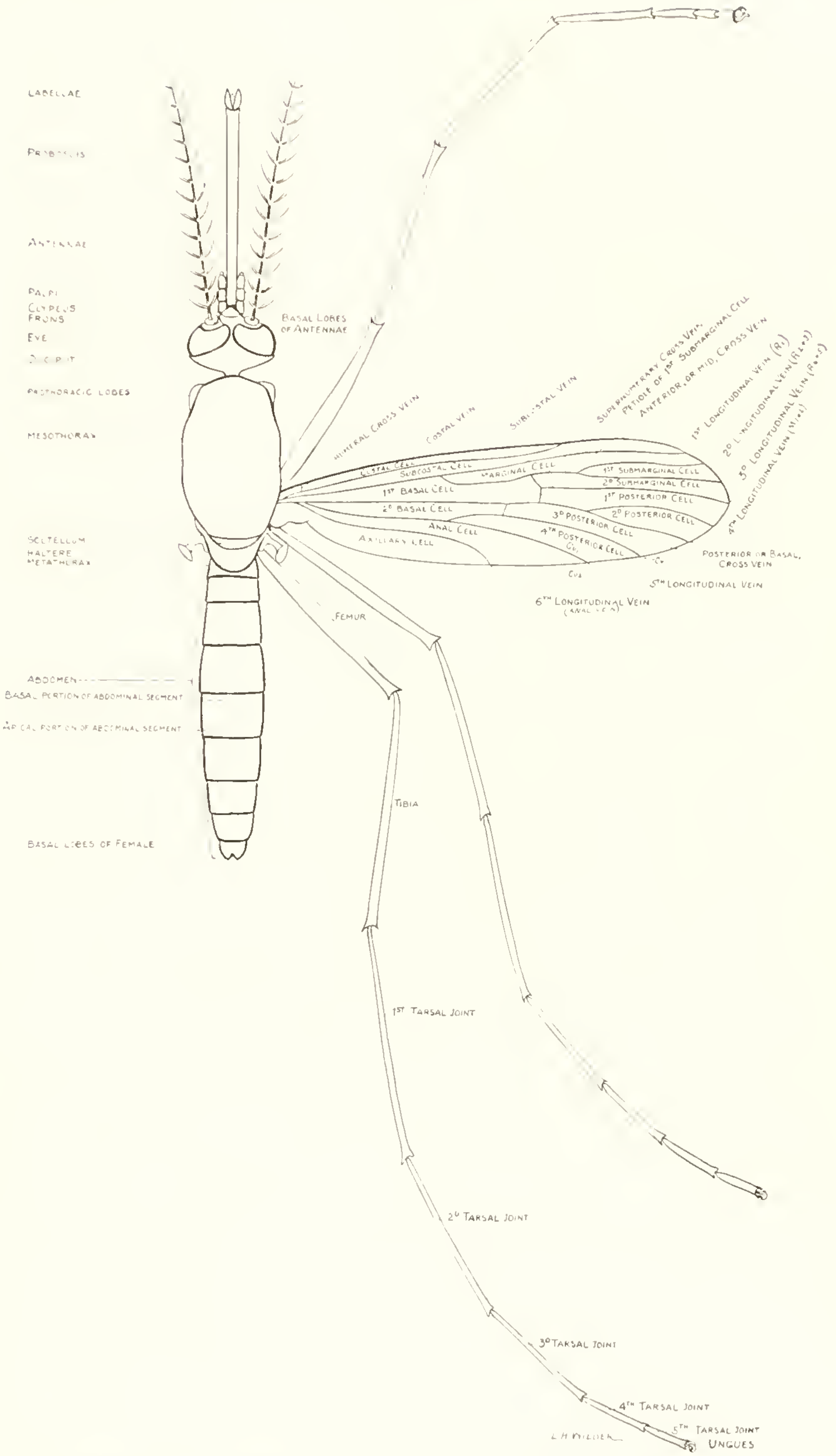

FIG. 1.—An adult mosquito to show anatomical parts (Semi-diagrammatic).

down, thus sawing a way through the skin until they meet a capillary blood vessel. As the stilette bundle, steadied by the labellae, enters the skin, the labium bends beneath as the piercing organs go deeper and deeper.

Lying a little above and on either side of the proboscis are two sensory organs known as the *palpi*. These are important in differentiating the species.

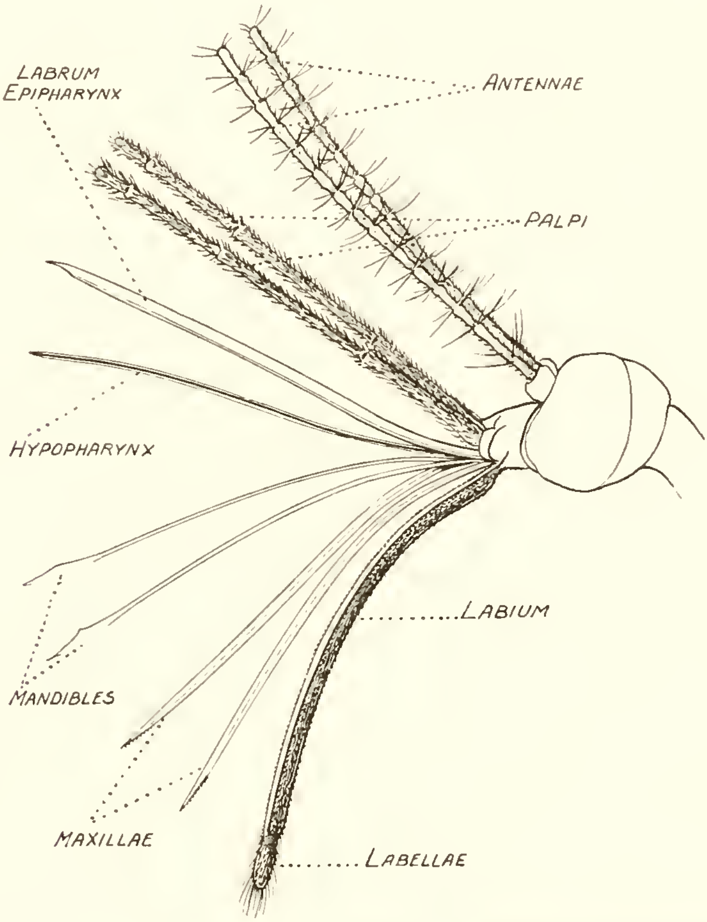

FIG. 2.—Mouth parts of a female mosquito (*Anopheles quadrimaculatus*).

Above the palpi on either side of the clypeus are the *antennae*, two in number. They are composed of 14 or 15 joints, all, except the basal joint, similar to each other. The antennae are important in differentiating the sexes, as stated below.

The Thorax.—The thorax is largely made up of the *mesothorax*. The *prothorax* in front and the *metathorax* behind are much reduced in size. The mesothorax has no transverse suture; it terminates behind in the *scutellum* which may be simple or trilobed; behind and beneath the scutellum is the *metathorax* sometimes called the *post-*

scutellum; attached to the mesothorax are two wings one on each side. Figure 3 gives a lateral view of the thorax.

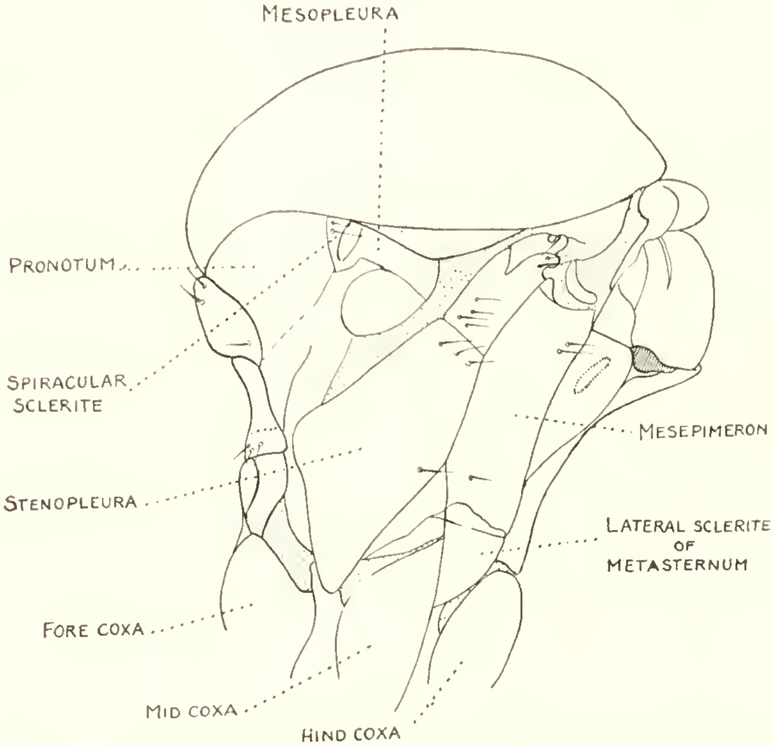

FIG. 3.—Lateral view of the thorax of one of the Culicidae (*Uranotaenia*). (From Dyar and Shannon in the Journal of Washington Academy of Sciences.) (Note: Stenopleura should read Sternopleura.)

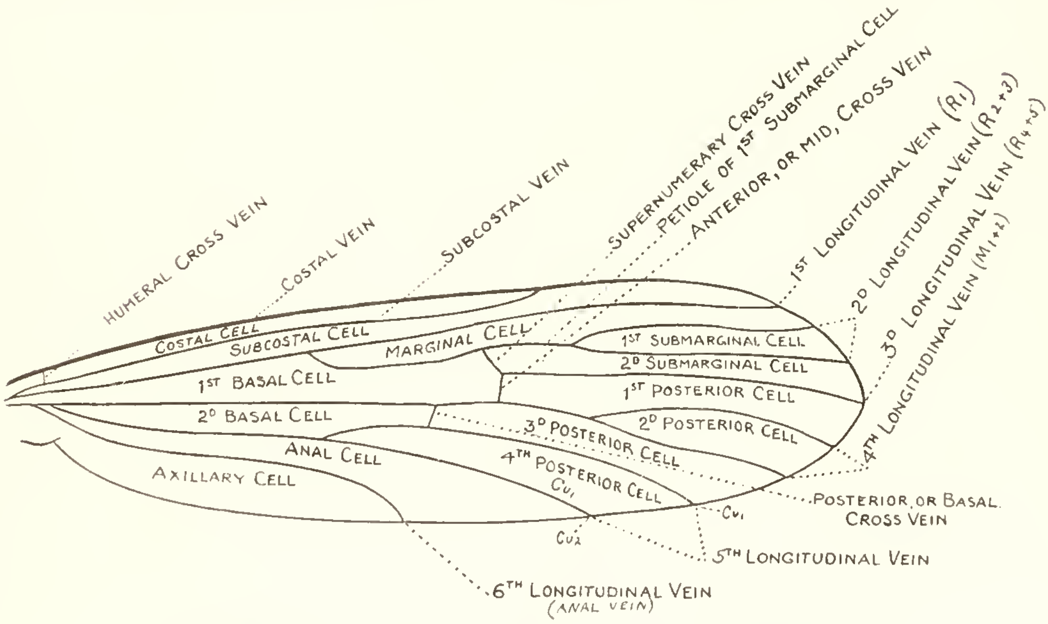

FIG. 4.—The wing of a mosquito to show wing veins and cells.

Wings. (Fig. 4). Each *wing* has *six longitudinal scaled veins* and *three* distinct *fork cells.* The *costal vein* extends all round the

margin of the wing its scales forming a fringe. The three fork cells are formed by the bifurcation of the second, fourth and fifth longitudinal veins. The wing veins from before backward are the *costal*, the *subcostal* or *auxiliary* vein and the *first, second, third, fourth, fifth,* and *sixth longitudinal veins;* or using another nomenclature, these veins would be known as, the Costal, Subcostal, Radius 1 (= 1st Longitudinal). Radius 2 + 3 (= 2nd longitudinal). Radius 4 + 5 (= 3rd longitudinal). Median 1 + 2 (= 4th longitudinal). Cubitus 1 + 2 (= 5th longitidunal) and anal 1 + 2 (= 6th longitudinal). These veins mark off hyaline areas on the wing known as cells which are from before backward the *costal* cell, the *subcostal* cell, the *1st.* marginal cell, the 2nd. marginal or first fork cell, the sub-*marginal* cell, the *1st. posterior* cell, the *2nd. posterior* or *second fork* cell, the *3rd. posterior*, the *4th. posterior* or *third fork* cell, the *anal* cell and the *axillary* cell (not to be confused with auxiliary which is not a cell but a vein). Attention should be paid to the *petiole* of the *2nd. marginal cell* which is that part of the second logitudinal vein between its bifurcation and the angular root of the third longitudinal. The *cross veins* should be noted. The *anterior cross* vein lies between the third and fourth longitudinal veins. The *basal cross vein* lies between the fourth and fifth longitudinal veins. The position of these cross veins with relation to each other should be noted. Near the base of the wing between the costal and auxiliary veins is the *humeral cross* vein. The angular bend at the beginning of the third longitudinal vein is sometimes spoken of as the "supernumerary cross vein." It is not a true cross vein.

Attached to the metathorax, behind and below the root of the wings, are the *halteres* or *balancers*, one on each side.

Comstock and Needham have adopted another system of terminology to designate the veins and cells of the wings of insects. Their system is based on the principle that all of the longitudinal veins are branches of certain main stems which are from before backwards, the Costa (C), Subcosta (Sc), Radius (R), Media (M), Cubitus (Cu), First Anal (1st. A), Second Anal (2nd. A) and Third Anal (3rd. A). Of these the Subcosta, Radius, Media and Cubitus may be branched, the number of branches varying in the different groups of insects. If, for example, one examines the basal half of the wing of a mosquito there will be seen anteriorly, first the costal vein which borders the wing, then the subcosta which terminates at the costal border approximately half way between the base and

the tip or apex of the wing, and then a vein which if followed up towards the apex of the wing is seen to branch or fork several times. This is the radius. Its first furcation forms two branches. The first branch is the vein which we have designated above as the 1st. longitudinal vein but which in Comstock's nomenclature would be known as Radius-one or vein R_1. The second branch known as the Radial sector (Rs) typically separates into four branches R_2, R_3, R_4, R_5, but in the mosquito only divides into three branches R_2, R_3, R_{4+5}, the latter designation indicating that, in the wing of a mosquito, Radial-four and Radial-five have coalesced. A wing cell takes its name from the vein which forms its anterior boundary. Thus the cell back of the Radius is known as cell R, that back of the first branch of the Radius, i.e. vein R_1, is known as cell R_1, and so forth. Cell Cu_1 is bounded in front by vein Cu_1. This cell is shown in the illustration (Fig. 4) as the 4th. posterior cell.

Legs.—There are *six legs*, one attached to either side of each thoracic sternite. Each leg is divided into nine segments. Beginning with the segment attached to the thorax these are, *coxa*, *trochanter* (both short), *femur*, *tibia*, and *five tarsal segments* (collectively tarsus). The last tarsal segment terminates in a pair of *claws*. The first tarsal segment, i.e. that next to the tibia, is sometimes called the metatarsus.

Abdomen.—The abdomen has *ten segments*, the last two being modified according to the sex. In the male these are termed the *hypopygium*. Arising from the 10th. segment of the female is a pair of appendages known as the *cerci*.

The genital armature of the male (Fig. 5) is carried on the hypopygium, the 9th. and 10th. segments which are crowded together. It consists of two thick conical appendages, *the side pieces*, each bearing a small terminal appendage, the *clasp filament* or *clasper*. There may also be lobes near the base or near the tip of the side pieces known as *subbasal* or *subapical lobes*. Three sets of paired basal appendages may be seen, the *harpes* or 10*th. sternite*, the *harpagones* or *claspettes* and the *unci* or *aedoeagus*. The 9th. segment usually has a pair of haired basal appendages.

Alimentary Tract. (Fig. 6).—When blood is sucked up through the canal formed by the apposition of the labrum-epipharynx and the hypopharynx, it first passes into the *buccal cavity* in the head; it then enters the *aspiratory pharynx* which dilates and collapses alternately, thus acting as a pump to draw the blood up from the

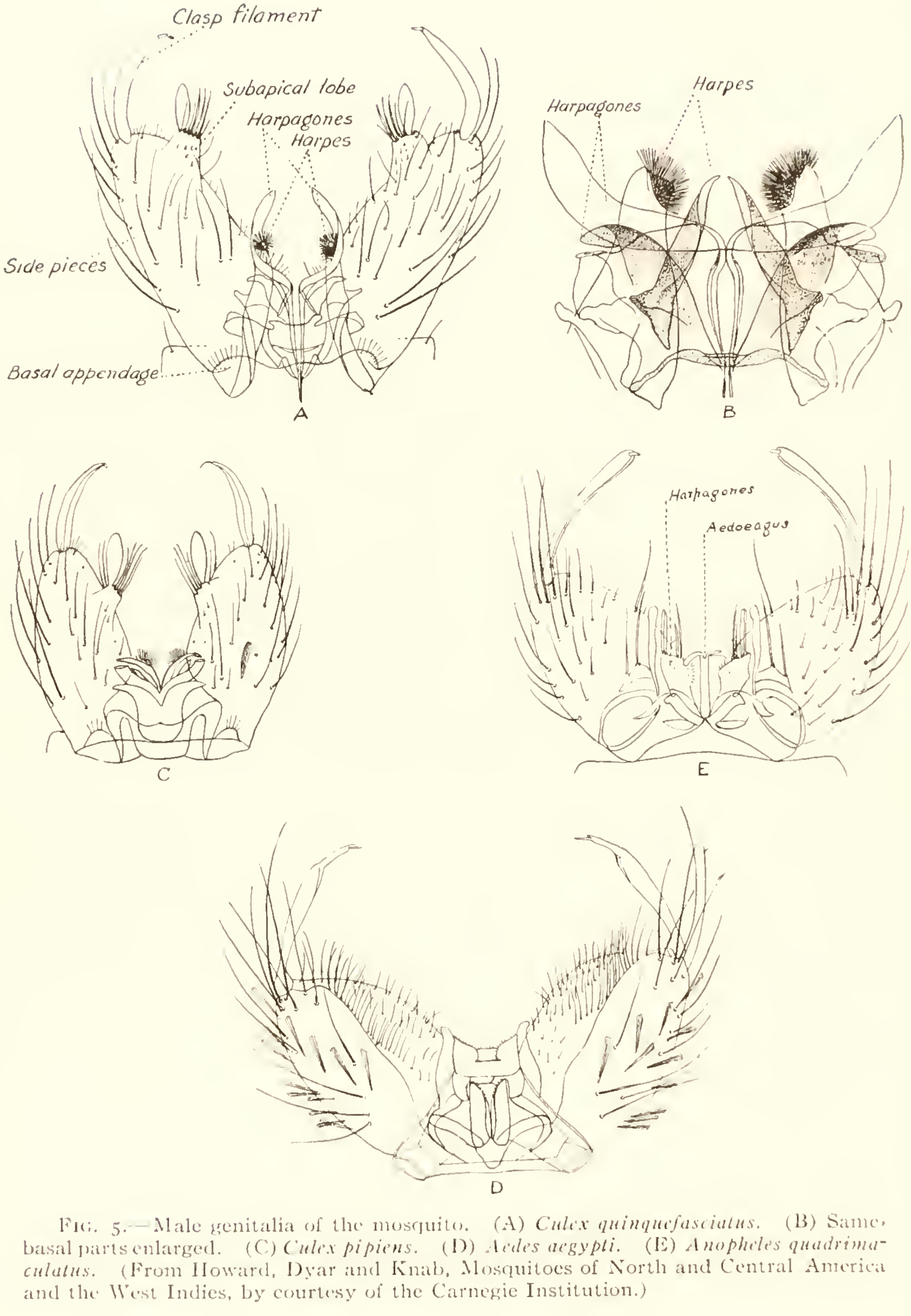

FIG. 5.—Male genitalia of the mosquito. (A) *Culex quinquefasciatus.* (B) Same, basal parts enlarged. (C) *Culex pipiens.* (D) *Aedes aegypti.* (E) *Anopheles quadrimaculatus.* (From Howard, Dyar and Knab, Mosquitoes of North and Central America and the West Indies, by courtesy of the Carnegie Institution.)

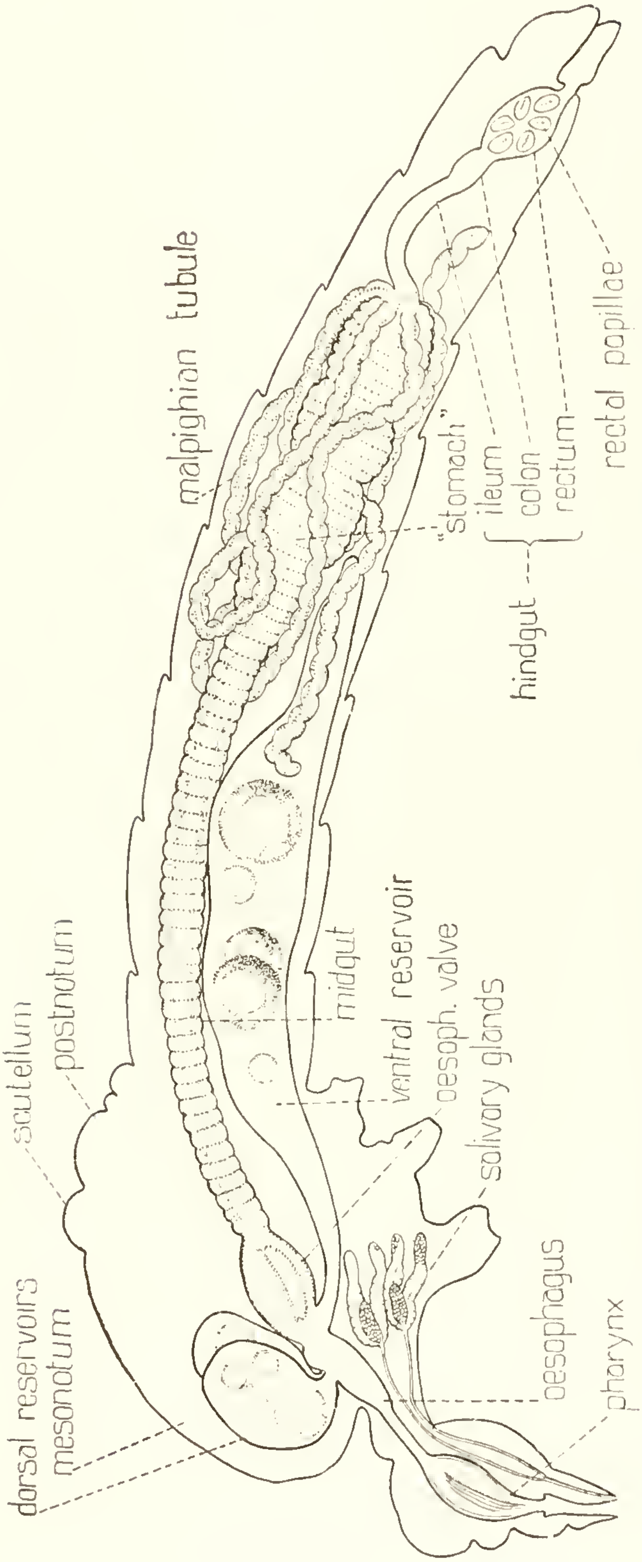

FIG. 6.—Showing internal anatomy of a female *Anopheles* mosquito. (From Herms' Medical and Veterinary Entomology, 2nd. Edition. Courtesy of the Macmillan Company.)

wound and then to force it backwards into a short *oesophagus;* connected with the latter are three thin walled pouches or food resevoirs called the *oesophageal diverticula*. The blood passes into the *mid-gut* or *stomach* through the *proventriculus* a musculo-valvular arrangement which prevents regurgitation. The mid-gut lies in the thorax and abdomen. Its first part is tubular. This part has been termed the *cardia*. The second part of the mid-gut, that part lying within the abdomen, is dilated and is the *stomach* proper.

The midgut is lined with a single layer of epithelial cells. These lie on a basement membrane outside of which is a layer of circular muscle fibers with a few scattered longitudinal fibres. It is in the stomach walls that the oocysts of malaria are commonly found. In the stomach, digestion and absorption take place and the residue passes into the *hindgut* or *intestine* and then into the *rectum* which contains the *rectal glands*. At the junction of the mid- and hindgut empty the *Malpighian tubules*, five in number.

The *salivary glands* lie ventrally in the anterior part of the thorax. There are two groups of glands of three each, a group on each side. They are tubular ascinous glands. The secreting portion consists of a single layer of cubical or short columnar cells resting on a basement membrane. The cells of the lateral glands in the group are compressed and the material in the lumen of the gland does not stain with eosin. The middle gland of the group is the smallest; its cells are not so compressed and contain more protoplasm and the secretion contained in the lumen of the gland stains with eosin. The ducts of each of the two groups unite to form two main ducts which pass into the head and then join to form a common salivary duct which empties into a salivary pump and finally becomes continuous with the salivary canal in the hypopharynx.

The Larva. (Fig. 7).—A mosquito larva or wriggler is composed of a *head*, *thorax* and *abdomen*. The head is large and more or less globular with a prominent dark colored *eye* on each side. In front of the eyes, one on each side, are the *antennae* which are provided at or near the middle (Equator) with a tuft of hairs called the *antennal tuft*. On the dorsal surface of the head are located three pairs of hair tufts named, from before backward, the *anteantennal tufts* and the *lower dorsal* and *upper dorsal head hairs*.

Projecting from the anterior and under part of the head are the *mouth brushes*. There are also a pair of *mandibles* and a pair of *maxillae*. In the mid (Sagittal) line at the posterior end of the

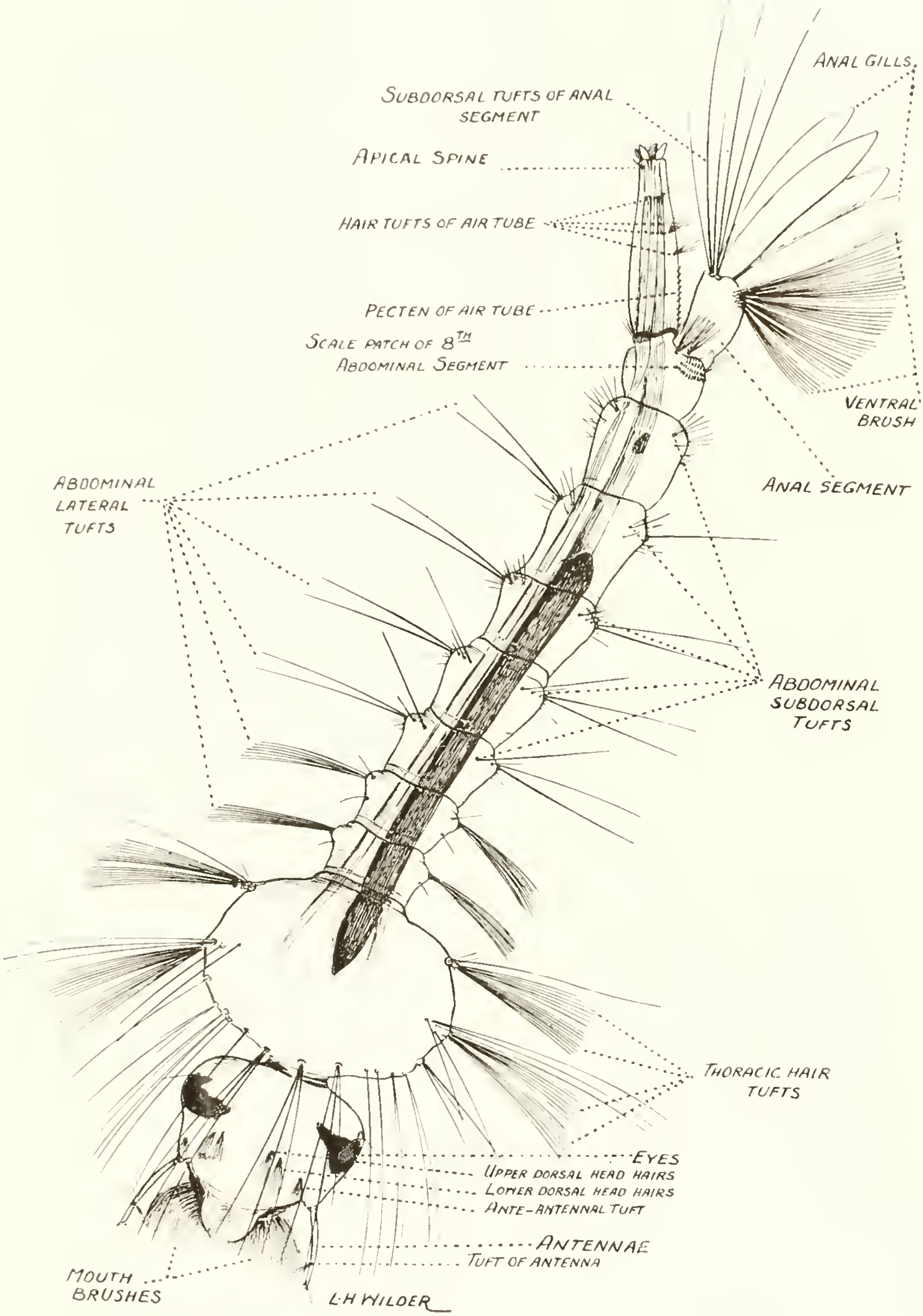

FIG. 7. Larva of a *Culex* mosquito (*Culex quinquefasciatus*).

mouth may be seen the *mental plate* or *mentum* which is in connection with the hypopharynx. It is a triangular, heavily pigmented plate of chitin with its edges serrated.

Arising from the sides of the thorax are numerous groups of hairs.

The abdomen is composed of *nine segments* each provided with hair tufts. On the 8th. segment is a patch of spines known as the *scale patch.* On this segment is also located the *breathing spiracle* which in the non-anophelines is to be found at the tip of a *siphon* or *breathing tube.* This tube may have a double row of spines—*the pecten*—which runs longitudinally from near the base. There is also one or more pairs of *hair tufts* along its length. The *9th. last* or *anal*, segment has a conspicuous tuft composed of many hairs and known as the *anal hair tuft.* This segment terminates in four membraneous projections, the *anal gills.* The 8th. segment may be ringed at the base. This ring may or may not extend around the entire circumference of the segment.

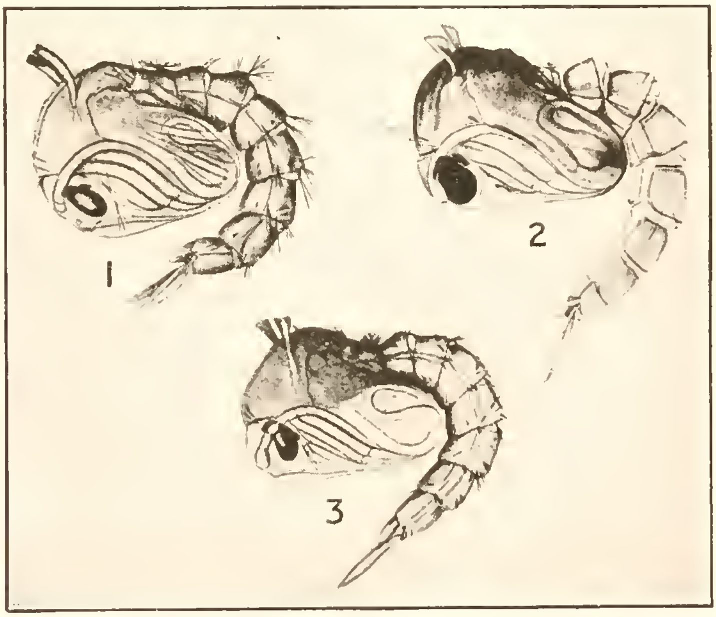

FIG. 8.—Mosquito pupae. (1) *Culex pipiens;* (2) *Aedes aegypti;* (3) *Anopheles punctipennis.* (From Stitt, after Howard, Dyar and Knab, by courtesy of Carnegie Institution.)

The Pupa. (Fig. 8).—The pupa of mosquitoes is active. In its formation the last larval skin is cast and the appendages and body are bound together by a closely applied layer of chitin. The adult emerges through a T-shaped slit in the dorsum of the thorax.

This is known as an *obtect* pupa. The pupa consists of an anterior swollen portion made up of the head and thorax, and a posterior shrimp-like tail, the abdomen. From the dorsum of the cephalothorax project a pair of siphon tubes—the breathing tubes.

Life History. The egg, larval and pupal stages of mosquitoes are spent in water. Ordinarily the eggs are laid on the surface of water but some species deposit their eggs above or at the margins of collections of water and some will even deposit their eggs on the dry mud of what were temporary puddles. Such eggs hatch soon after rain water has collected. The larva and pupa can not survive except in water. It has been shown however that the larvae of certain mosquitoes may live for periods as long as fourteen days in damp surroundings such as moist earth and moistened filth paper. Usually they breathe by bringing the breathing tube to the surface thus securing oxygen from the air, but the species of one genus (*Mansonia*) attach themselves to the roots of certain water plants and thus derive oxygen from the plant. Mosquito larvae are voracious, some predaceous. The pupa does not feed. The egg stage lasts from 24 to 48 hours. The larval stage lasts from five to ten days depending upon temperature. The pupal stage lasts from 48 to 72 hours also depending upon the temperature. Warm weather hastens, cool weather delays development.

CHAPTER IV

CULICIDAE (CONTINUED)

CLASSIFICATION AND IDENTIFICATION OF MOSQUITOES

To be able to identify all mosquitoes an elaborate key to the classification is necessary. It is however, an easy matter to determine whether a mosquito may be one of interest as a known carrier of disease.

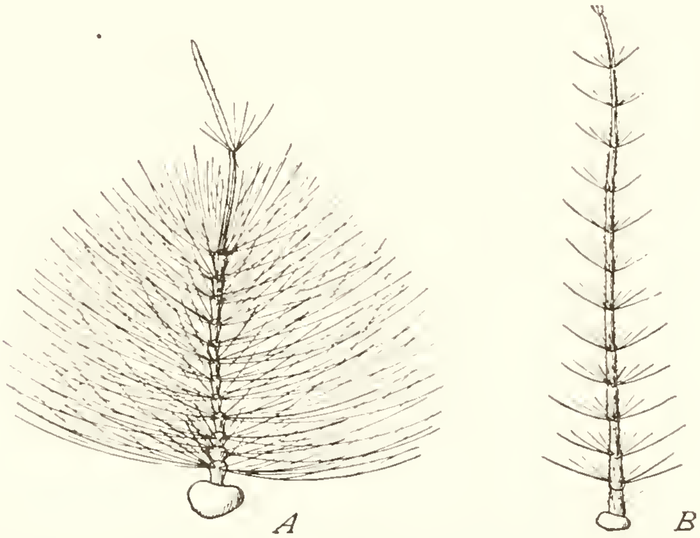

Fig. 9.—Antennae of mosquito, *Culex pipiens*. A, male; B, female. The antenna has a short basal segment, not shown in the figure. (From Folsom's "Entomology," 3rd. Edition.)

In the first place the mosquitoes are the only members of the Order which have wings bearing scales. In all other Diptera the wings are naked or contain hairs or perhaps a few bristles but never scales.

Then, usually only the females bite. The males live on the juices of fruits and flowers, therefore, it is necessary to distinguish between males and females. In the forms of interest in preventive medicine this can be done by the form of the antennae. In the female the antennae are only sparsely decorated with short hairs and are therefore inconspicuous. In the male the antennae are generously decorated with longer hairs in whorls giving them a feathery or

plumose appearance and rendering them very conspicuous. (Fig. 9.) If the antennae have been broken off it may be necessary to examine the terminal abdominal segments where, if a male, the clasping organs may be noted.

Having determined the sex it is then necessary to distinguish between the Anophelines to which group belong the malaria carrying mosquitoes, and the Culicines to which belong the carriers of certain other diseases.

In the Anophelines the palpi in both sexes are more than half as long as the proboscis. The proboscis in the female is straight. In the Culicines the proboscis is straight or only slightly curved and the palpi in the female are less than half as long as the proboscis.

The anophelines have a characteristic position when at rest. (Fig. 10.) They rest with the abdomen forming a straight line with the proboscis and at an angle to the resting surface. The Culicines rest with the abdomen forming an angle with the proboscis and more or less parallel to the resting surface.

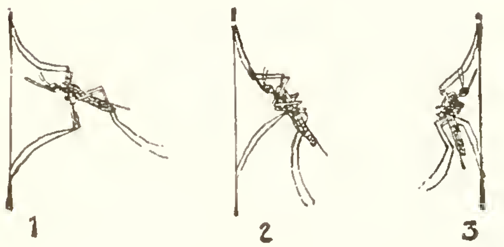

FIG. 10.—Resting position of mosquitoes; 1 and 2, *Anopheles*; 3, *Culex pipiens*. (From Stitt, after Sambon, from P. H. Reports.)

FIG. 11.—Egg mass of *Anopheles quadrimaculatus*. (After Howard.)

The wings of the Anophelines are usually spotted (Fig. 14), those of the Culicines unspotted.

The Anophelines lay their eggs singly, but deposited in groups so as to form patterns as for instance, a ribbon or triangle. The eggs rest horizontally on the surface of the water supported by the air cells, "floats," which may be seen as little projections on each side. (Fig. 11.) The shape of these air cells differs somewhat according to the species. The egg is flat above, convex below, with

an outline somewhat oval or boat shaped. Among the Culicines, the eggs of *Aedes aegypti* (*Stegomyia fasciata*) are laid singly on the sides of the receptacle above the level of the surface of the water. Each is surrounded by a pearl-necklace-like fringe. *Culex* lays its eggs in rafts, each egg standing vertically. The dark brown raft

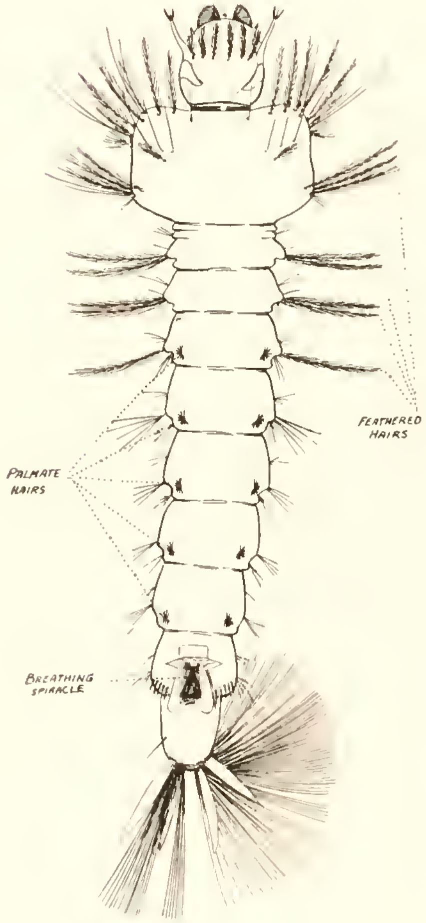

FIG. 12.—An Anopheline larva (*Anopheles quadrimaculatus*).

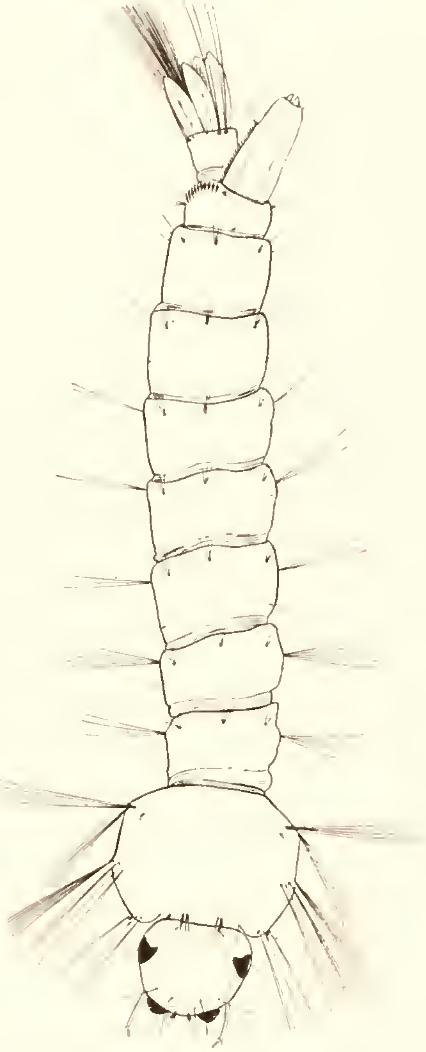

FIG. 13.—Larva of *Aedes aegypti*.

is convex below and concave above. These egg rafts of *Culex* are readily seen. Eggs laid singly are more difficult to detect.

With regard to the larvae it may be said that those of the Anophelines, (Fig. 12), instead of hanging head down from the surface of the water as in the case of *Culex* and *Aedes*, lie with the body close to and parallel with the surface of the water. There are other aquatic Nematocerous insects (Chironomidae, and *Uranotaenia*

a non-anopheline mosquito) which also lie parallel to the surface of the water and which on superficial examination might be mistaken for Anopheline larvae. Anopheline larvae have no siphon tube, but breathe through a stigmatic opening on the eighth segment. Culicine larvae have a drawn out siphon tube, at the end of which is a breathing spiracle. The siphon in *Culex* is long and slender (Fig. 7), while in *Aedes* it is relatively short and barrel shaped. (Fig. 13.)

Projecting from the sides of the thorax and abdominal segments of Culicine larvae are groups of straight hairs. (Fig. 7.) In the Anopheline larvae many of these hairs branch laterally, that is, they are feathered; (Fig. 12) and in addition there is dorsally on each side of some of the abdominal segments, a group of palmate hairs.

The larvae of *Culex* wriggle rapidly to the bottom when disturbed. Larvae of *Aedes aegypti* wriggle to the bottom more slowly than *Culex* larvae, their bodies describing curves with much greater arcs. Anopheline larvae while they may wriggle to the bottom when disturbed, usually move rapidly along the surface of the water. The head of an Anopheline larva is much narrower than the thorax and the antennae project straight forwards. Larvae of Anophelines are variously colored,— green, gray, reddish, brown or black.

With regard to the pupae, (Fig. 8), the breathing tubes of *Culex* are long and slender and arise from the posterior (caudal) portion of the cephalo-thorax. Those of the Anophelines are broad and funnel shaped and arise from the middle (equator) of the dorsum of the cephalo-thorax. The siphons of *Aedes* are short and broad and the opening is triangular in shape.

Key to the Subfamilies of Culicidae (H. G. Dyar and R. C. Shannon,* 1924)

A1. Eyes reniform; flagellum 13-jointed; proboscis extending far beyond clypeus; mesosternum ridged; sternopleura not divided by transverse suture (except Uranotaenini); lateral sclerite of metasternum triangular, in line with (Megarhinini, Sabethini) or below (Uranotaenini, Anophelini, Culicini), the base of hind coxa; wings scaled, hind margin with fringe of scales; Rs forking far before tip of Sc; upper squama bare or ciliated (Page 34) .... *Culicinae*

A2. Eyes more or less emarginate on mesal line; flagellum 13-jointed; proboscis extending very short distance beyond clypeus; mesosternum without ridge; sternopleura divided by transverse suture; lateral sclerite of metasternum much reduced, not triangular; wings with hair-like scales, hind margin with fringe of scales; Rs forking far before tip of Sc; upper squama ciliated .... *Chaoborinae* (Corethrinae)

* Journal of the Washington Academy of Sciences, Vol. 14, No. 20, pp. 475–478.

A3. Eyes not emarginate, nearly circular in outline; flagellum 14-jointed; proboscis not extending beyond clypeus; mesosternum without ridge; sternopleura nearly divided by a median transverse suture; lateral sclerite of metasternum much reduced, not triangular; wings with only inconspicuous hairs on veins, hind margin with fringe of sparse hairs; Rs forking approximately opposite tip of Sc; upper squama not ciliated. *Dixinae*

Key to the Genera of American Culicidae (Dyar and Shannon)*

A1. Proboscis extending far beyond clypeus.............Subfamily *Culicinae*.

B1. Base of hind coxa in line with upper margin of lateral metasternal sclerite; upper squama incompletely ciliated to bare; spiracular setae not absent when pronotal setae are present; (exclude *Haemagogus*, Culicini, by: spiracular setae absent; proepimeral setae present)..........**Series A.**

C1. Clypeus much broader than long; scutellar post margin evenly rounded; a spurious vein in Cu_1 cell; squama not ciliated; post notal setae absent.............................MEGARHININI, *Megarhinus*.

C2. Clypeus at least as long as broad; scutellum trilobed; no spurious vein in Cu_1 cell; post notal setae present; abdomen usually compressed and with few setae..........................SABETHINI.

D1. No pronotal setae (lobes widely separated, see *Isostomyia espini*).

E1. No prealar setae.

F1. No propleural setae...............................*Sabethes*.

F2. Propleural setae present........................*Sabethoides*.

E2. Prealar setae present.

F3. No spiracular setae...............................*Limatus*.

F4: Spiracular setae present.

G1. Lower sternopleurals distinctly below upper margin of lateral metasternal sclerite.

H1. Wing scales especially the outstanding scales on bases of R_2 and R_3 broad..........................*Miamyia*.

H2. Wing scales narrow.........................*Wyeomyia*.

G2. Lower sternopleurals, extending as far as, usually above, upper margin of lateral metasternal sclerite.

H3. Wing scales narrow (rare)...................*Menolepis*.

H4. Wing scales broad.........................*Prosopolepis*.

D2. Pronotal setae present (except *Isostomyia espini*).

E3. Clypeus without setae.

F5. Lower sternopleurals distinctly below upper margin of lateral metasternal sclerite; palpi very small in both sexes. *Isostomyia*.

F6. Lower sternopleurals extending above upper margin of lateral metasternal sclerite; palpi not small...............*Goeldia*.

E4. Clypeus setose......................................*Joblotia*.

B2. Base of hind coxa distinctly below upper margin of lateral metasternal sclerite; postnotum rarely setose; abdomen rarely compressed and with reduced setae. (The Sabethid-like genus *Haemagogus* is retained

here on basis of absence of spiracular setae and presence of pronotal setae)........................ Series B.

C3. Scutellum trilobed with marginal setae only on the lobes.

D3. Anal vein extending well beyond fork of cubitus; wings villose; upper squama ciliated (partially so in *Haemagogus* and *Carrollia*)..................................CULICINI (Page 30).

E5. Prescutellar setae absent; wings narrower than width of thorax; postspiracular setae absent..........................*Haemagogus*.

E6. Prescutellar setae present; wings broader than width of thorax.

F7. Post spiracular setae present.

G3. Spiracular setae absent.

H5. Wing scales mostly narrow, or when broad (rare), setae are present on upper side of base of first vein......*Aëdes*.

H6. Wing scales broad; setae absent on upper side of base of first vein. (See *Mansonia*.)

G4. Spiracular setae present, sometimes small......*Psorophora*.

F8. Post spiracular setae absent.

G5. Lower side of base of first vein distinctly pilose; spiracular setae present...............................*Culiseta*.

G6. Lower side of base of first vein scaly or bare; spriacular setae absent.

H7. No setae on upper side of base of first vein; wing scales broad, black and pale mixed (all black in some species of *Mansonia* which have post spiracular setae).

I1. No mid-mesepimeral setae; fourth tarsal joint of fore tarsus somewhat thickened, as broad as long, or broader. *Orthopodomyia*.

I2. Mid-mesepimeral setae present; fourth fore tarsal joint longer than broad.

J1. Post marginal wing scales longer than width of anal cell; antennal joints but little longer than broad. *Adëomyia*.

J2. Post marginal wing scales shorter than width of anal cell; antennal joints much longer than broad. *Mansonia*.

H8. Setae present on upper side of base of first vein; wing scales mostly narrow, dark colored.

I3. Mid-mesepimeral setae numerous...............*Lutzia*.

I4. Mid-mesepimeral setae 0-3.

J3. Antenna much longer than lengh of proboscis. *Deinocerites*.

J4. Antenna approximating length of proboscis (Page 30) *Culex*.

D4. Anal vein ending opposite or basad of cubital fork; squamae not ciliate; wings without villi.

URANOTAENINI, *Uranotaenia* (Page 47).

C4. Scutellum crescent-shaped, with marginal setae evenly distributed.

ANOPHELINI, *Anopheles* (Page 34).

A2. Proboscis not elongate, extending but little beyond clypeus.

B3. Radial sector forking far before tip of subcosta; wings with hair-like scales; hind margin with fringe of scales.......Subfamily *Chaoborinae*.

C5. Anal vein ending basad of cubital fork....................*Eucorethra*.

C6. Anal vein ending beyond fork of cubitus.

D5. Basitarsal joint shorter than following joint..............*Corethra*.

D6. Basitarsal joint longer than following joint.

E7. Tip of R_1 much nearer tip of R_2 than to Sc...........*Chaoborus*.

E8. Tip of R_1 much nearer tip of Sc than to R_2..........*Corethrella*.

B4. Radial sector forking approximately opposite tip of subcosta; wings with only inconspicuous hairs on veins, hind margin with fringe of sparse hairs...............................Subfamily *Dixinae*. *Dixa*.

Key to the Larvae (Howard, Dyar, and Knab, 1917)*

Anal segment without ventral brush, the hair tufts all paired...Tribe Sabethini Genus *Wyeomyia*

Anal segment with unpaired ventral median brush..............Tribe Culicini

1. Air tube short, sessile, the larvae surface feeders...............*Anopheles*
   Air tube distinctly elongate.......................................2
2. Air tube without pecten...3
   Air tube with well developed pecten...............................5
3. Mouth brushes of lamellate prehensile plates................*Megarhinus*
   Mouth brushes normal..4
4. Air tube with the outer half attenuated......................*Mansonia*
   Air tube cylindrical or fusiform; antennae small, slender...*Orthopodomyia*
5. Air tube with but a single pair of ventral (posterior) tufts...........6
   Air tube with several pairs of ventral tufts, mouth brushes normal with no prehensile hooked lamellae..................................*Culex*
6. Head elongate elliptical.......................................*Uranotaenia*
   Head nearly circular or transverse................................7
7. Air tube pecten produced into long hairs; hair tuft close to base..*Culiseta*
   Air tube pecten of short scales or if produced the hair tuft remote from base..8
8. Mandibles angularly projecting laterally.....................*Deinocerites*
   Mandibles concealed...9
9. Anal segment ringed by plate, with ventral hair tufts piercing the ring. *Psorophora*
   Anal segment not ringed, or if so with the hair tufts posterior to the ring. *Aedes*

Key to the Species of Anopheles of North and Central America and the West Indies (Howard, Dyar and Knab, (1917)*

1. Tarsi ornamented with white or yellow...............................2
   Tarsi wholly dark colored...13

* The Mosquitoes of North and Central America and the West Indies. Published by the Carnegie Institution of Washington.

2. Hind tarsi with a series of rings.......................5
Hind tarsi all white beyond second joint.......................3
Hind tarsi white beyond second joint, a black spot on the last joint......4
3. Abdomen dorsally covered with scales.
A. argyritarsis Robineau-Desvoidy (Page 38)
Abdomen clothed dorsally with hairs only.......................*A. lutzii* Cruz
4. Palpi with the last two joints white except narrowly at bases.
A. tarsimaculata Goeldi (Page 38)
Palpi with the last joint only white.....*A. albimanus* Wiedemann (Page 38)
5. Hind tarsi with small basal rings only; palpi wholly black scaled.
A. grabhamii Theobald
Tarsi more conspicuously ornamented; palpi not wholly black scaled.....6
6. Tarsi and tibiae narrowly ringed and speckeled black and white or yellow 8
Hind tarsi with broad apical segmental white rings; not speckeled........7
7. Wings with four white spots on the costa........*A. bellator* Dyar and Knab
Wings with two white spots on the costa; five on the first vein.
A. neivai Howard, Dyar and Knab
8. Wing scales mostly blackish, many little patches of yellow ones.
A. vestitipennis Dyar and Knab
Wing scales black and white or yellow, several large concrete patches of black scales.......................9
9. Hindtarsal joints with apical rings; last joint wholly black.
A. maculipes Theobald
Hind tarsi with rings involving both ends of the joints; last joint mostly or wholly pale scaled.......................10
10. Wing scales broad and rounded.......................11
Wing scales narrowly ovate to lanceolate.......................12
11. Tarsi yellow with small black dots.............*A. mediopunctatus* Theobald
Tarsi black with white rings.............*A. malefactor* Dyar and Knab
12. Hind tarsi with numerous yellow rings....*A. strigimaculata* Dyar and Knab
Hind tarsi with sparse white ring...........*A. apimaculata* Dyar and Knab
13. Hind tibiae without a white apical ring.......................14
Hind tibiae broadly white at apex..................*A. eiseni* Coquillett
14. Wings with a white spot at outer third of costa.......................15
Wings without such spot on the costa.......................16
15. Palpi marked with white, third vein extensively white in the middle, wing fringe spotted................*A. pseudopunctipennis* Theobald (Page 37)
Palpi wholly black scaled, third vein wholly black scaled, wing fringe unspotted.......................*A. punctipennis* Say (Page 37)
16. Wings with patches of yellowish scales, sixth vein with three black spots.
A. crucians Wiedemann (Page 36)
Wings without patches of pale scales.......................17
17. Wings at apex with a coppery spot on the fringe.
A. occidentalis Dyar and Knab (Page 38)
Wing fringe uniformly dark throughout.......................18
18. Body blackish throughout; hair scales of mesonotum dark brown.
A. atropos Dyar and Knab

Body not wholly blackish; hair scales of mesonotum yellow or white.....19

10. Palpi of the female with dull silvery white rings at the bases of the joints; scales of wing not distinctly massed at bases of fork cells.
A. walkeri Theobald

Palpi of female blackish scaled throughout; scales of wings massed to form distinct spots at cross veins and at bases of fork cells.
A. quadrimaculatus Say (Page 34)

Key to the Larvae

Larvae without respiratory siphon.

1. Scales of scale patch with teeth all long, equal....................*neivai*

Scales of scale patch alternately long and short................*malefactor*
strigimaculata

Teeth of the comb both long and short, irregular......................2

2. Abdomen with seven pairs of dorsal fan shaped tufts, the pair on first segment small..*albimanus*
tarsimaculatus

Abdomen with six pairs of fan shaped tufts............................3

Abdomen with five pairs of well developed tufts......................5

3. Elements of fan shaped tufts slender, smoothly pointed.......*argyritarsis*

Elements of fan shaped tufts notched towards tip....................4

4. Fan shaped tufts all equal in size.................................*eiseni*

First pair of tufts small...................................*punctipennis*
quadrimaculatus

5. First and last pair of tufts smaller than the others..............*crucians*

Fan shaped tufts all equal..6

6. Elements of fan shaped tufts with long slender apical portion.
pseudopunctipennis

Fan shaped tufts with normal elements......................*occidentalis*
(*maculipennis*)
grabhamii

In a campaign against the mosquito borne diseases many different species of mosquitoes will be collected which are not carriers of disease although they may be a great nuisance in the locality. Komp has worked out a key to be used by field workers for the determination of the species of adult females and larvae commonly encountered, especially in the Southern United States.

Key for Determining Species of Adult Female Mosquitoes (Komp) (1923)*

Wings spotted, palpi almost as long as the proboscis.......................1

Wings unspotted, palpi much shorter than the proboscis....................4

1. Palpi ringed and tipped with white..2

Palpi uniformly dark brown..3

* Public Health Reports, Vol. 38, No. 20, May, 1923, pp. 1070 1080.

2\. Sixth longitudinal vein with three black spots (Page 36).
A. crucians Wiedemann
Front margin of wing with three light spots. 6th. longitudinal vein basally pale, apically black (Page 37)..........*A. pseudopunctipennis* Theobald
3\. Prominent white spot on front wing margin, 6th. longitudinal vein white with black ends, median gray thoracic stripe (Page 37).
A. punctipennis Say
Four dark spots on wing, 6th. longitudinal vein wholly dark scaled, no thoracic stripe (Page 34). ....*A. quadrimaculatus* Say
4\. Legs banded or marked with white..............................5
Legs unbanded, uniform in color..............................11
5\. Proboscis centrally ringed with white..............................6
Proboscis unbanded........ 8
6\. Abdomen with dorsal longitudinal stripe, sides of thorax white below black stripe (Page 44).................. ....*Aedes sollicitans* Walker
Abdomen without dorsal stripe..............................7
7\. Large blackish species, tibia white spotted, femur white banded near tip, abdomen unbanded (Page 46).....*Psorophora columbiae* Dyer and Knab
Small blackish species, tibia and femur unmarked, abdomen banded with white at bases of segments (Page 45).
Aedes taeniorhynchus Wiedemann
8\. Thorax marked with lines or stripes..............................9
Thorax unmarked..............................10
9\. Large yellowish species, with broad yellow median thoracic, stripe, legs heavily fringed with upright scales (Page 46).
Psorophora ciliata Fabricius
Small black species, thorax marked with white lyre shaped design, palpi white tipped, abdominal segments with lateral white spots (Page 43).
Aedes aegypti (*Stegomyia fasciata*)
10\. White markings of legs narrow, abdominal bands nearly divided in the middle (Page 44)..............................*Aedes vexans* Meigen
Large purplish species, with two terminal joints and apex of middle joint of hind tarsi white (Page 47)..........*Psorophora sayi* Dyar and Knab
11\. Abdominal segments banded with white at the apex only (Page 42).
Culex testaceus van der Wulp
Abdominal segments banded with white at base only..................12
12\. Under side of abdomen with unbroken black bands (Page 42).
Culex erraticus Dyar and Knab
Under side of abdomen not completely banded.......... 13
13\. Upper side with narrow white or yellowish basal bands................14
Abdomen unbanded dorsally, lateral spots of the abdomen not visible dorsally, (Page 41). *Culex salinarius* Coquillett
14\. Band on second abdominal segment somewhat triangular................15
This band transverse (Page 41)...... . ...*Culex territans* Walker
15\. Abdominal bands joined to the lateral spots (Page 40).
Culex pipiens Linnaeus
Abdominal bands separated from the lateral spots (Page 40).
Culex quinquefasciatus Say

Key to Full-grown Mosquito Larvæ

	Without breathing tube, lying parallel with water surface in surface film	1
	With breathing tube; when breathing, hanging from surface film at an angle	2
1.	Palmate hairs on abdominal segments 3 to 7 equal in size.	*A. quadrimaculatus.* *A. punctipennis.*
	Palmate hairs on abdominal segments 3 and 7 smaller than those on segments 4, 5, and 6	*A. crucians.*
2.	More than one pair of hair tufts or hairs on breathing tube	10
	A single pair of hair tufts on breathing tube	3
3.	Abdominal hair tufts star-shaped; head pear-shaped, with four coarse head hairs (Page 47)	*Uranotænia sapphirinus.*
	Abdominal hair tufts not star-shaped; head not pear-shaped, head hairs slender	4
4.	Breathing tube very short, dorsal head hairs single (found in salt water)	5
	Breathing tube at least three times longer than wide (found in fresh water)	6
5.	Breathing tube not more than twice as long as wide; scale of eighth abdominal segment with long central spine (Page 44)	*Aëdes sollicitans.*
	Breathing tube not more than one and one-half times as long as wide, scale of eighth abdominal segment rounded at tip, fringed with slender equal spines (Page 45)	*Aëdes tæniorhynchus.*
6.	Head square, almost straight across front; antennæ arising from near middle of sides of head; mouth brushes prominent, at outer angles of head; a very large larva when full grown (Page 46).	*Psorophora ciliata.*
	Head normal, rounded; antennæ arising from sides of front of head	7
7.	Scales of eighth abdominal segment 6 or 7, joined at bases to a band; breathing tube large, swollen, with four or five strong spines	8
	Scales of eighth abdominal segment 10 to 50, not joined to a band, but arranged in a triangular patch; breathing tube short, not swollen, with a double row of small spines	9
8.	Antennæ shorter than head (Page 46)	*Psorophora columbiae.*
	Antennæ much longer than head, slender, slightly curved.	*Psorophora sayi.*
9.	Dorsal head hairs multiple, antennal tuft multiple; last two spines in row on breathing tube larger, separated from the rest, and from each other (Page 44)	*Aëdes vexans.*
	Dorsal head hairs single; antenna with single hair replacing usual tuft; breathing tube dark, barrel-shaped; a long, slender larva found in artificial containers (Page 43)	*Aëdes ægypti.*

Antenna with tuft arising from middle of uniformly shaped joint; tufts of breathing tube replaced by six long, coarse hairs.

Culex restuans.

10\. Antenna with tuft arising from a notch two-thirds the distance from base to tip of joint, part beyond tuft slender; breathing tube with from 6 to 10 hair tufts.... 11

11\. Breathing tube long, slender, about seven times as long as wide.......12

Breathing tube about three times as long as wide...................13

12\. Dorsal head hairs single, scale patch of eighth abdominal segment of many scales in a triangular patch (Page 42).... ....*Culex testaceus.*

Dorsal head hairs multiple; scale patch as in *C. testaceus* (Page 41).

Culex salinarius.

Lower dorsal head hairs long, single; upper pair short, multiple; scale patch of eighth abdominal segment of few, sharp, pointed scales in an irregular double row (Page 42).......................*Culex erraticus.*

13\. Dorsal head hairs multiple; scale patch of many scales in a triangular patch; breathing tube slightly swollen at base, bottle-shaped; breeding by preference in polluted water; a very common species (Page 40).

Culex quinquefasciatus.

CHAPTER V

SUBFAMILY CULICINAE

TRIBE ANOPHELINI

Palpi as long as or longer than the proboscis in both male and female and in the male more or less clubbed at the end; proboscis straight; scutellum simple, never trilobed; metanotum nude.

In the Western Hemisphere all of the malarial carriers are found in the Genus *Anopheles*. (Malaria, Chap. XXV.)

Genus Anopheles (Meigen)

Description.—With scales on the head and wings, often hair like scales only on the thorax and abdomen; mostly upright forked scales on the head; the scales on the wings are large and lanceolate; the palpi are usually only slightly scaled; second marginal cell at least as long as its petiole; mesothorax elongate, over twice as long as wide; scutellum rounded not lobed, with scales or hairs; metanotum nude; antennal segments in the female are without dense lateral scale tufts; these are present in the male; wings with six scaled longitudinal veins.

ANOPHELES QUADRIMACULATUS (Say)

A. quadrimaculatus has four black spots on the second and fourth wing veins. The palpi are uniformly dark brown and the sixth vein is wholly darked scaled.

Habits.—This mosquito is rather fastidious in its choice of a breeding place and much prefers clean, clear, quiet water, such as large ponds and grassy puddles. It will not breed in sewage polluted water. It breeds especially in ponds of considerable width and depth but when more favorable breeding places are scarce it may be found in small pools and occasionally in post holes, hoof prints, and rarely at the edges of slow moving streams where there is practically no surface flow. In ponds it is ordinarily found near the edge in shallow water, sheltered and protected by water plants,

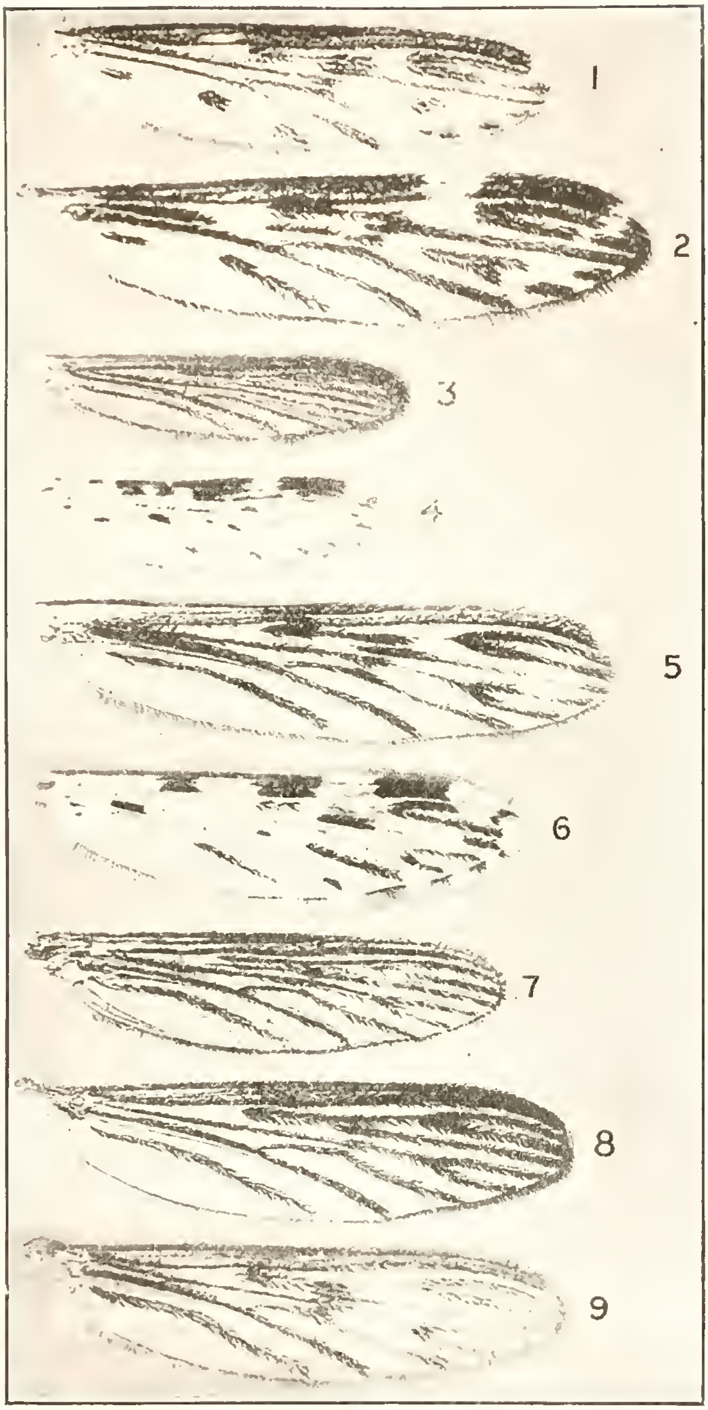

FIG. 14.—Wings of *Anopheles* mosquitoes shown to the same scale. (1) *A. crucians;* (2) *A. punctipennis;* (3) *A. barberi;* (4) *A. albimanus;* (5) *maculipennis;* (6) *A. pseudo-punctipennis;* (7) *A. atropos;* (8) *A. walkeri;* (9) *A. quadrimaculatus.* (From Stitt, after Howard, Dyar and Knab, by courtesy of Carnegie Institution.)

but it has been reported from the middle of a large pond in six feet of water where floatage (broken pieces of wild celery and pollen) furnished protection by preventing any break in the waves, thus permitting only long, smooth swells, and also furnishing protection against fish.

A. quadrimaculatus enters occupied dwelling houses in large numbers and therefore comes into intimate contact with people at the time it is ready to feed. It may be guided into the house by lights, even by light reflected up the chimney, and it may enter a house by way of the chimney as well as through unscreened windows and doors and through crevices and cracks in the walls and floors of poorly constructed houses. It is also found in out buildings such as privies. It perhaps prefers the blood of man to that of animals. It may fly as far as 1 1/4 miles from its breeding place. This is not usual, but from 1/2 to 1 mile is a common flight for *A. quadrimaculatus*. The greater the amount of breeding the greater the number that will be found at a distance from the breeding place, and the greater the tendency towards long flight up to the maximum. *A. quadrimaculatus* is an efficient carrier of *Plasmodium vivax*, *P. falciparum* and *P. malariae*. Probably most malaria is contracted at night in the house from the bite of this Anopheline. It may be found from Mexico to New England, east of the Rocky Mountains.

ANOPHELES CRUCIANS (Wiedemann)

A. crucians has the wings heavily spotted, the front margin darkest. The sixth vein has three dark spots one at each end, one at the middle. In the female the terminal joints of the palpi are white throughout, the penultimate joint is white at the base and apex, and the longest joint has a white ring near its middle.

Habits.—*A. crucians* also may be found in inhabited dwelling houses. It is not so widely distributed as are the other species. It bites on porches and is commonly found under the house or around the house in out-houses, privies, stables etc., and seems to prefer the blood of animals to that of man. Its maximum flight distance is probably the same as that of *A. quadrimaculatus*. It may be found breeding side by side with other *Anopheles* but may adapt itself to brackish water as in salt marshes, or water containing small amounts of chemicals, conditions under which neither *A. quadrimaculatus* nor *A. punctipennis* will breed. *A. crucians* is a proven

transmitter of *Plasmodium falciparum* and *P. vivax*. It may be found in the eastern United States from New York to Mexico; and in Cuba and Jamaica.

ANOPHELES PUNCTIPENNIS (Say)

Anopheles punctipennis has the front margin of the wing dark except for a conspicuous yellow-white patch about one quarter the way from tip to base, with a smaller white patch near the tip. The sixth vein is dark scaled at both ends and light in the middle. The palpi are uniformly brown and the thorax has a wide pale gray longitudinal stripe.

Habits. This mosquito is more widely distributed and more numerous than either of the other species. It is most in evidence in the early evening. It is rarely found in occupied dwelling houses and then usually after cool weather has set in. It is a biter on porches and is found under houses and in out houses, pig pens and the like. It seems to prefer the blood of animals to that of man. It does not fly far from its breeding places which may be streams, ditches and springs as well as small ponds, marshy areas or other places where *A. quadrimaculatus* will breed. It is occasionally found breeding in artificial containers, and may also develop in brackish water. Slight pollution of the water does not deter it from breeding. *Anopheles punctipennis* is a proven carrier of *Plasmodium vivax* and *P. falciparum*.

The latter two species of mosquitoes are less important disseminators of malaria than *A. quadrimaculatus* because they do not enter houses so readily and as the Anophelines are shy they are not so apt to bite while persons are moving about outside of the house.

Except in the arid regions *A. punctipennis* is found in the United States from Mexico to Canada.

ANOPHELES PSEUDOPUNCTIPENNIS (Theobald)

The front margin of the wing has three light spots, one about one-third the distance from base to tip, one about two-thirds and one at the extreme tip. The sixth vein is white at the base and black in the outer half. The fringe on edge of the wings has pale spots at tips of all veins. The palpi have the tips white, the base and apex of penultimate joint are banded with white and there is a white ring near the middle of last joint. The markings of the palpi differ-

entiate this species from *A. punctipennis* in which the palpi are unbanded.

Habits.—This mosquito is found in the southwestern part of the United States, southern California and Texas, and extends down through Mexico and Panama into South America. It may enter houses. It breeds in pools, ditches, and at the edges of streams, preferring clear pure water. *A. pseudopunctipennis* is a proven carrier of *P. falciparum.*

ANOPHELES ARGYRITARSUS (Robineau-Desvoidy)

This mosquito has been found to breed in small collections of water such as seepage pools, hoof prints, swampy pastures, ditches containing but a small amount of water and in artificial containers. The presence of algae is necessary. The adults bite at dusk and during the night. Panama, Brazil.

ANOPHELES ALBIMANUS (Wiedemann)

This mosquito breeds in fresh, brackish or even definately salt water but not in foul water. Larvae have been taken in swamps, hoof prints, wheel ruts and seepage water. The adult enters occupied houses in large numbers. It is found in Tropical America, the Antilles and southern Florida.

ANOPHELES TARSIMACULATA (Goeldi)

This mosquito breeds in fresh or brackish water but not in foul water. Larvae have been found in rivers, swamps, ditches, small water holes and in artificial containers. The adults enter dwellings at dusk and leave in the early morning. Panama, Porto Rico.

ANOPHELES MACULIPENNIS (Meigen)

This is a medium sized blackish mosquito with four dark spots on wing as follows—base of second vein in the cell, on the cross veins and forks of second and fourth vein. The tip of the wing shows a coppery reflection in the fringe. In America this mosquito is known as *occidentalis.* In Europe it is a common vector of malaria and, it also plays a part in the spread of malaria in the Western United States. It breeds in water puddles preferring permanent water. It is found in Europe, Asia, Western United States (except

the most northern Pacific strip) eastward through Canada to Northern Maine.

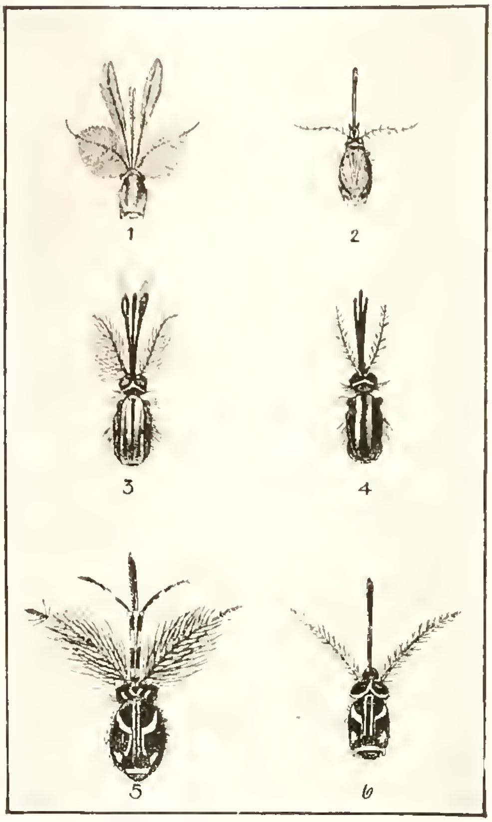

FIG. 15.—Head and thorax of mosquitoes; 1 and 2, male and female *Culex quinquefasciatus;* 3 and 4, male and female *Anopheles;* 5 and 6, male and female *Aedes aegypti.* (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology" 7th. Edtion.)

TRIBE CULICINI

In this tribe the palpi in the male are as long or longer than the proboscis, in the female shorter than the proboscis; the proboscis is straight; the metanotum nude and the scutellum trilobed.

Genus Culex (Linnaeus)

Adult.—The scales on the occiput and vertex are narrow and curved with numerous forked scales on the occiput and laterally a patch of flat scales. The scutellum is trilobed and clothed with narrow, curved scales. The wing scales are usually long and narrow. The palpi in the female are three-segmented, in the male not clubbed but hairy. The basal cross vein is remote from the anterior cross vein.

Larva.—All species of *Culex* considered herein (included in Komp's key) have more than one pair of tufts on the breathing tube. This immediately separates them from the larvae of other genera. In all species except *Culex territans* the antennal tufts project from an offset about two-thirds the distance from the base to the tip; the antenna are thick at the base and the part beyond the tuft slender.

CULEX QUINQUEFASCIATUS (Say) (=FATIGANS)

Adult.—This important member of the Genus *Culex* transmits filariasis (Chap. XXVIII). The mosquito has a wide distribution over the Tropics and warmer parts of the Temperate Zone. In the North it is represented by *Culex pipiens* Linnaeus. Both are found in the vicinity of Washington D. C. The proboscis and legs are uniformly dark brown in color, not ringed or spotted.

C. pipiens has the thorax clothed with narrow, curved, golden-brown scales; the abdomen has continuous pale bands at the bases of the segments joining the lateral spots, the band at base of second segment somewhat triangular; the petiole of the first submarginal cell is from one-fifth to one-sixth as long as its cell. It has a northern distribution and is common in Europe, Asia and North America from Virginia to Canada. It is also found in Chili and Argentine.

In *C. quinquefasciatus* the thorax has a more grayish appearance and the bands on the abdomen are separated from the lateral spots. The petiole of the first submarginal cell is about one-fourth as long as its cell. There are also differences in the male genitalia.

Larva.—The larvae of *C. pipiens* and *C. quinquefasciatus* (Fig. 7) are very much the same except that in *C. pipiens* the breathing tube is about five times as long as wide, there are about fifteen teeth in the pecten and the subdorsal hairs on the abdominal segments are three or four double. In *C. quinquefasciatus* the breathing tube is about four times as long as wide, there are about nine teeth in the pecten and the subdorsal hairs on the abdominal segments are three or four single.

The air tubes of both taper rather rapidly after the middle. On the air tube are four paired tufts of hairs the third pair being out of line. The antennal tufts are outwardly placed with the part beyond slender. The scale patch on the eighth segment consists of many scales (about 40) in a triangular patch. These scales are finely fringed at the tip.

Habits. *C. quinquefasciatus* is the common house mosquito of the Tropics and Subtropics. It is domestic in its habits and not at all fastidious as to its breeding place but seems to prefer filthy water and may commonly be found breeding in cess pools, sewers, catch basins, collections of filthy water in low areas being filled by city wastes, dirty water in artificial containers and the like.

It may bite at any time outside but it is especially troublesome in the house at night and during the afternoon if the room is darkened. *Aedes aegypti* and *Culex quinquefasciatus* have a similar distribution. The latter is essentially a night biter while the former bites in the day time.

CULEX SALINARIUS (Coquillett)

Adult.—This mosquito closely resembles *C. quinquefasciatus.* The abdomen is blackish above with or without narrow, basal, whitish bands joining the lateral spots. It is found in the eastern part of the United States.

Larva.—The larva has a very long slender breathing tube, about seven times as long as broad. Eight small tufts occur between the spines and the tip of the tube. The paired head hairs are multiple.

CULEX TERRITANS (Walker)

Adult.—This mosquito also closely resembles *C. quinquefasciatus.* The abdomen is blackish brown above with basal segmental whitish bands transverse and even. It is found in Eastern North America from the Gulf of Mexico to Canada.

Larva.—It is much like *C. quinquefasciatus* but instead of the antennal tufts arising from an offset about two-thirds the distance from the base to the tip of the antenna as it does in *C. quinquefasciatus* and other members of the Genus *Culex* mentioned herein, the tuft arises from the middle of an evenly tapering antenna. The tufts on the breathing tube are replaced by six long, coarse hairs with a small tuft near the tip.

Habits.—*Culex salinarius* and *C. territans* resemble *C. quinquefasciatus* closely in appearance and habits and they are often found associated with each other. *C. territans* prefers cleaner water than *C. quinquefasciatus* and is more frequently found in rural sections in dirty ground puddles. It is often found in rain barrels. Like *C. quinquefasciatus* it is a house mosquito and bites at night. *C.*

salinarius is often found in fresh water pools near the sea, but it also occurs inland and may breed in rain barrels. Its habits are similar to the others.

CULEX TESTACEUS (van der Wulp)

Adult.—A small blackish mosquito. The legs are unbanded and uniform in color. The abdominal segments are banded with white at the apex only. It has a wide distribution in the United States and Europe.

Larva.—The breathing tube is very long and slender, seven times as long as wide. There are eight small hair tufts between the pecten and the tip. The head is broader than the thorax. The antennae are light colored at the base and darker beyond the tuft. Both pairs of dorsal head hairs are single. This differentiates from the larva of *C. salinarius* which also has a very long breathing tube but which has multiple head hairs.

Habits.—*Culex testaceus* breeds in permanent pools filled with aquatic vegetation. It is often found associated with *Anopheles* larvae or with the three Culicids mentioned above in rain barrels and other artificial containers. It does not bite man.

CULEX ERRATICUS (Dyar and Knab)

Adult.—This is a small black species with unbanded proboscis and legs, characterized by the unbroken black band on the under side of the abdomen, a mark found in no other common mosquito.

Larva.—The larva is small, often bright green. The bases of the antennae are conspicuously white. The first pair of head hairs is long and single, the second, short multiple tufts. The scale patch of the eighth segment consists of an irregular double row of sharp pointed scales not fringed at tip. The breathing tube has five pairs of very long tufts beyond the pecten. The body is very hairy (pilose) which character separates it from all other common Culex larvae.

Habits.—This is a species inhabiting the southern Mississippi Valley into Georgia and Florida. The larvae are common in permanent bodies of water covered with duck weed, associated with the larvae of *Anopheles* and *Uranotaenia sapphirinus*. The adult will enter houses but is not very troublesome.

Genus Aedes (Meigen)

Adult.—The scales on head and scutellum are broad and appressed. The palpi of the female are short, acuminate and sparsly tufted, palpi of the male long and tufted. Palpi with three segments in the female, the three segments equal in length. Metanotum nude. Legs uniformly scaled with flat scales. First submarginal cell long.

Larva.—The larvae have scale patches consisting of a few to many pointed scales not finely fringed as in Culex. There is only one pair of tufts beyond the spines on the breathing tube and the antennae are usually uniformly tapering with the tuft at or near the middle.

AEDES AEGYPTI (Linnaeus) (STEGOMYIA FASCIATA)

Adult.—This important member of the genus is the mosquito which carries yellow fever and dengue (Chaps. XXVI and XXVII). It is blackish, marked with silvery white. The thorax has two median broken silvery white lines and lateral curved silvery lines, these markings taking the form of a lyre. The proboscis is not banded. The abdominal segments are ornamented with lateral, triangular, silvery white spots. The tarsal segments are banded at their bases with silvery white, and the last joint of the hind tarsi is wholly white. The claws of the female are toothed at least on front and middle legs. The clypeus is white scaled. This is a tropical mosquito but, in summer is also found in temperate regions.

Larva. (Fig. 13).—The air tube is short and stout a little more than twice as long as broad. It has a single pair of tufts beyond the pecten. The teeth of the pecten are long and evenly spaced in a regular row. Each spine has two large and a few small teeth near the base. The scales of the patch on the eighth abdominal segment are few in number (about ten) in a single row. Each spine has a pointed base and a long terminal spine with several curved spines at each side. The plate of the anal segment does not form a complete ring around it. The antennae are usually uniformly tapering with a single hair instead of a tuft, at or near the middle.

Habits.—This mosquito is distinctly domestic in its habits breeding in and around houses in bottles, cans, pots, cisterns, water barrels, buckets, roof gutters, bases of flower-pots, etc. which contain clean, fresh water. In the absence of natural breeding places the mosquito may deposit her eggs in small pools around a house which

contain clean fresh water or perhaps in street gutters or collections of water in the axils of leaves or knot holes in logs or trees. When hard pressed they have even been found breeding in slop jars and chambers containing dirty water. Under such circumstances it is probable that complete development rarely takes place. They do not like muddy water and will not breed in cess pools.

The yellow fever mosquito does not fly far from its place of birth probably not more than 75 or 100 yards or not farther than the houses of adjoining neighbors, but they may be carried by ships and perhaps by trains as well. The eggs are laid at or just above the water level and will withstand drying for a long period—six or seven months.

AEDES VEXANS (Meigen) (=SYLVESTRIS)

Adult.—This is a medium sized, brownish black mosquito with the proboscis unbanded and the thorax uniformly brown in color. There is a narrow, dirty white ring at the base of each tarsal joint. The abdominal bands are constricted at the centre so that a B-shaped band is formed at the base of each abdominal segment more noticeable on the terminal segments. This mosquito is found in North America from Mexico to Canada, except on the Pacific Coast and the far north.

Larva.—The head is widest behind the eyes, tapering towards the front. Both pairs of dorsal head hairs are multiple. The scale patch on the eighth segment is composed of from 10 to 15 scales in an irregular double row, each scale sharply pointed at the tip and finely fringed on the side. The breathing tube is about three times as long as wide. The last two teeth of the pecten are separated from the pecten and from each other.

Habits.—This is an early spring species breeding in woodland pools or in open swamp pools. The common wood mosquito. It seldom enters houses but may be troublesome near its place of breeding.

AEDES SOLLICITANS (Walker)

Adult.—This is the salt marsh mosquito. It is golden brown in color, the proboscis is centrally banded with white, the sides of the thorax are silvery gray beneath a black edge. The bases of abdominal segments have a wide yellowish white band which is crossed longitudinally by a broad line of same color extending down

the centre. The base of each tarsal joint is broadly ringed with white and the last joint of hind tarsus is wholly white. It is found along the coast from Mexico to New England.

Larva. The larva is stout and chunky with a very short breathing tube. Both pairs of dorsal head hairs are single and rather long. The antennal tuft is small and arises from the middle of the antenna. The scale patch on the eighth segment consists of from 20 to 40 scales, each scale being elliptical in shape and having a sharp terminal spine and its sides fringed with smaller spines.

Habits. The salt marsh mosquito breeds in salt or brackish pools on tidal marshes. Aided by the wind it may fly long distances from its breeding places (40 miles or more) and bites during the day especially in the late afternoon.

AEDES TAENIORHYNCHUS (Wiedemann)

Adult.—This mosquito resembles *Aedes sollicitans*. It is smaller and blackish with no dorsal, central abdominal stripe. The proboscis is ringed centrally with a narrow white band. The tarsi have a narrow white band at the base but the last joint of the hind tarsus is wholly white. In a form occurring in Florida the last joint of the hind tarsus is largely black. (*Aedes portoricensis* Ludlow.)

Larva. The larva resembles that of *A. sollicitans* but it has a shorter breathing tube which is not more than one and one half times as long as wide. Each scale of the scale patch is rounded at the tip and is fringed with from 10 to 14 spines all alike but smaller towards the base of scale. The spines of the pecten may be toothed on the sides with three or four small teeth.

Habits. Similar in habits to *Aedes sollicitans*.

Genus Psorophora (Robineau-Desvoidy)

In this genus there are two subgenera, *Psorophora* proper in which the larvae are predaceous and *Janthinosoma* in which the larvae are not predaceous.

Subgenus Psorophora. Larva.—The head is quadrate and widest between the eyes. The antennae are set well back on the sides of the head. The scales of the scale patch are large and placed in a single row with a large patch of very small scales above them. The breathing tube is large and swollen and tapers rapidly from middle to tip.

Subgenus Janthinosoma. Larva.— The scales of the scale patch are few and arranged on a band. The breathing tube is large and swollen, tapering from middle to tip and provided with a double row of a few coarse, strong spines.

PSOROPHORA CILIATA (Fabricius)

Adult.—This is a very large mosquito. The proboscis is not banded. The thorax has a broad central band of yellowish brown scales. On each side of this band is a bare shining yellow area wider at the posterior end. There are no spots or bands on the abdomen. The tips of all femora are fringed with dense scales. The tibiae of middle and hind legs and hind tarsi are similarly scaled, except for yellowish white bands at base of each tarsal joint. It is found in the Eastern and Southern United States.

Larva.—A very large larva. The head is almost square but broadest between the eyes, almost straight across the anterior margin. The antennae are set well down along the sides. The mouth brushes are large and set at the anterior corners of head. The breathing tube is large and swollen and tapers from the middle to the tip. There are from 20 to 30 very long slender teeth in the pecten with one or two teeth at the base. Each of the large scales of the scale patch has a long terminal spine with one or two smaller spines on each side.

Habits.—This giant mosquito breeds in temporary puddles. Its larvae prey upon other larvae. The adult is a hard biter but seldom troublesome except near its breeding place.

PSOROPHORA COLUMBIAE (Dyar and Knab)

Adult.—A large brownish black mosquito, spotted and mottled with dull white. The proboscis has a broad dirty white band and the wings are rather heavily scaled. The abdomen is not particularly marked with bands or spots. The femora of the first pair of legs are marked near the apex with a narrow white band; the middle femora have almost no marking while those of the hind legs have a broad white band near the apex. The tibiae are black with a white spot near the base and many spots of white along one side. The first tarsal joint of the hind legs has a broad white band in centre which is less noticeable on the corresponding joints of the fore and mid legs. All the tarsal joints are ringed with white at their bases

except the fifth joints of fore and middle legs which are wholly black. It is found in Cuba, the Bahamas, Florida, and Texas northward.

Larva.—The larva is large and chunky with short curved antennae. The tuft is about at the middle of the antenna and the dorsal head hairs are multiple. The scales of the scale patch are six in number and attached to a band at their bases. Each scale has a long terminal spine with a curved subapical spine and two or three smaller spines along each side. The breathing tube is stout and swollen, tapering from middle to tip, with three to five strong spines in the pecten, each spine with one short tooth at the base. There is a small paired tuft beyond the pecten.

Habits. Larvae of this species develope rapidly in rain water pools in warm weather. Eggs are laid in the dry mud at the bottom and hatch almost immediately after contact with water. After hatching the cycle is completed in five days. The adults are not aggressive and troublesome only about their breeding places.

PSOROPHORA SAYI (Dyar and Knab)

Adult.—This is a wood species, a large metallic purplish mosquito with the tips of the hind legs only pure white. It is found in the Atlantic and Gulf States as far North as Southern Ontario, also in Cuba and the Bahamas.

Larva.—Similar to the larva of *P. columbiae* but the antennae are very long, slender and curved, with the tuft at the middle. The spines of the pecten are three or four in number. Each tooth has a broad base and there are a number of smaller teeth at the base of the long terminal spine. The scale patch is similar to that of *P. columbiae*.

Habits.—*Psorophora sayi* breeds in woodland pools. Adults are troublesome in the woods, never leaving the shade, but they bite fiercely during the day.

TRIBE URANOTAENINI

Uranotaenia sapphirinus (**Osten Sacken**).—Larvae are commonly associated with *Anopheles* larvae in pools with much vegetation. The larva holds itself parallel to the surface of the water and, like *Anopheles*, often darts sideways when disturbed. It can be differentiated immediately from *Anopheles* larvae by the presence of a breathing tube. This tube is short, very slender

and not tapered. The head of the larva is pear shaped, and smaller than the thorax as in *Anopheles*. The dorsal head hairs are single. The antenna has a single hair replacing the usual tuft. The abdomen is provided with long star shaped tufts of hair at the sides and on the back. The adults are seldom seen and do not bite. It is found in the Eastern United States from the Gulf of Mexico to northern New England.

CHAPTER VI

SUBORDER ORTHORRHAPHA

SECTION NEMATOCERA (CONTINUED)

Families Chironomidae, Simuliidae, Psychodidea

Certain other Families belong to the Section Nematocera and are therefore related to the mosquitoes and not infrequently confused with them. Many are a source of great annoyance. One at least is known to be a carrier of disease. The most important of these Families are the Chironomidae or midges; the Simuliidae, sand flies or buffalo gnats; and the Psychodidae or moth midges.

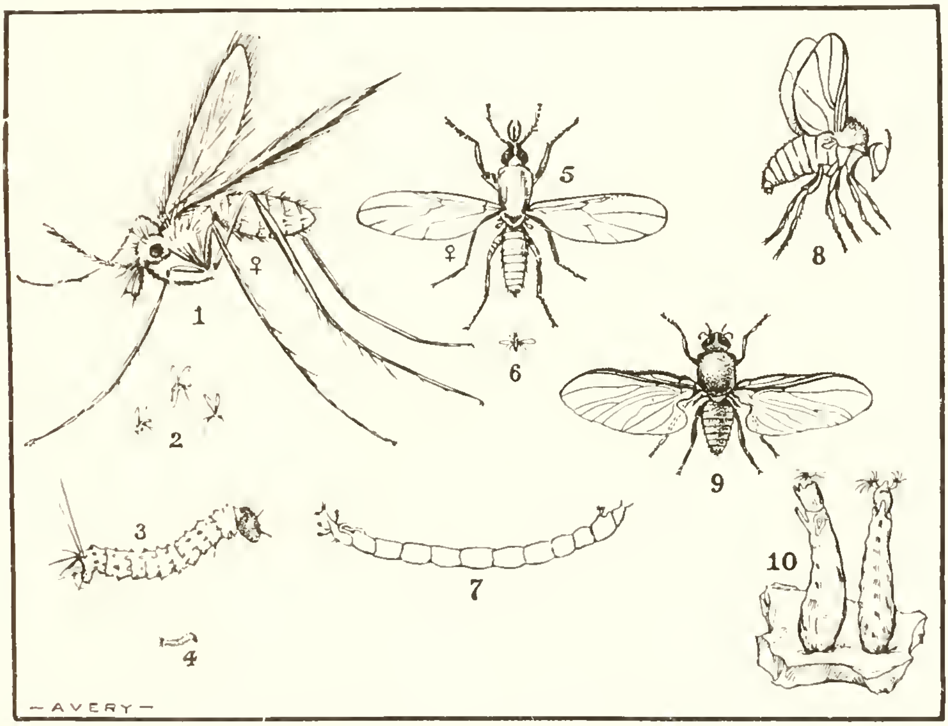

Fig. 16. Mosquito-like insects belonging to the families Chironomidae, Simuliidae and Psychodidae. (1) *Phlebotomus papatasii;* (2) *P. papatasii* (natural size); (3) *P. papatasii* (larva); (4) *P. papatasii* larva (natural size); (5) *Culicoides pulicaris* (Chironomidae); (6) *C. pulicaris* (natural size); (7) *Chironomus* larva; (8) Attitude of a *Simulium;* (9) *Simulium reptans;* (10) Larvae of *Simulium*. (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology" 7th. Edition.)

These insects are mostly small in size, many of them being able to pass through the meshes of an ordinary mosquito bar. Many

of them are vicious biters and extremely troublesome. Some breed in water, others require only moisture.

The sand fly (*Simulium reptans*) a member of the Family Simuliidae was at one time thought to be implicated in the occurrence of pellagra. *Phlebotomus papatasii*, a member of the family Psychodidae, is a carrier of Pappatici fever.

Family Chironomidae

(Midges)

Adult.—The Chironomidae are small to medium sized flies with a small head often retracted under and covered by the thorax. Ocelli are absent. The palpi are short with two to five segments. The eyes are reniform (kidney shaped). The antennae have from six to fifteen joints; they are pectinate in the male, simple and composed of fewer joints in the female. There is no transverse suture on the thorax. The wings are somewhat narrow and without a vein along the posterior margin, the costal vein ending near the tip of the wing. The fourth vein is often and the fifth vein is usually forked. The legs are long and slender.

Egg.—The eggs are small, ovoid or long and pointed. They are laid in water, sometimes on land, separately or in a gelatinous string of mucous.

Larva.—The larval stage is usually spent in water—such as the blood worms found in streams and stagnant pools. The larva has 13 segments. The head is directed downward and the mandibles are well developed. Delicate processes (gills) may be seen on the under surface of the 11th. and 12th. segments.

Pupae.—The pupae are free, floating in water or on the bottom. Breathing tubes are on the dorsum of the thorax.

Family Simuliidae

(Sand flies—Buffalo gnats)

Adult.—The Simuliidae are small, robust hump backed flies without ocelli. The antennae are short, straight, cylindrical, eleven jointed and without long hairs. The palpi are small and incurved. The eyes of the male are large and meet in the middle line, while those of the female are smaller and separate. The wings are broad (Fig. 17). There is no trans-

FIG. 17. Wing of *Simulium* (Simuliidae).

verse suture on the thorax. The legs are short and the posterior tibiae and the first joint of the hind tarsi are dilated.

Eggs.—The eggs are small, ovoid and yellowish in color. They are laid on or under the surface of water, in masses attached to blades of grass, leaves, stones, etc.

Larvae.—The larvae always live in water attached to objects by a posterior sucker. Anteriorly there are two large fan-like processes. This is characteristic. The larva may wander in the stream still attached to an object by a long spun silken thread. (Fig. 18.)

Pupae.—The larva spins a pupal case. The pupa within it has long, chitinous, branched, breathing tubes on each side of the thorax.

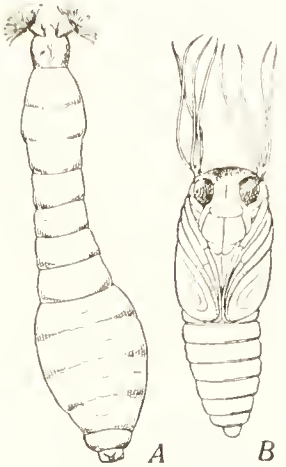

FIG. 18.—*Simulium*; A, larva; B, pupa, showing respiratory filaments. (From Folsom's "Entomology," 3rd. Edition.)

Family Psychodidae

(Moth midges)

Adult.—The Psychodidae are small flies without ocelli and with the body densely covered with coarse hairs. The antennae are long, twelve to sixteen jointed and little different in the sexes. The thorax has no transverse suture and is not greatly arched. The wings are broad and hairy. There are six or seven longitudinal veins, the 2nd. and 4th. forked, the 2nd. sometimes forked twice.. (Fig. 19.) There is no discal cell. The legs are long with hairs or scales. Claws long. Male genitalia large and conspicuous.

FIG. 19.—Wing of *Phlebotomus* (Psychodidae).

Egg.—The eggs are elongate, dark brown in color with longitudinal dark, wavy lines, laid singly or in clusters in dark, damp places, attached to a surface by a sticky substance.

Larva.—The larva lives in dark, damp places. The head is large with large well developed mouth parts. The segments of the body are spiny. Posteriorly there are two pairs of black caudal bristles, one pair as long as the body.

Pupa.—The thorax is ridged. The larval skin is found adherent to the last abdominal segment.

PHLEBOTOMUS PAPATASII SCOPOLI

This moth midge is about two mm. long. Its body is densely covered with long grayish hairs. The second longitudinal vein has two distinct branches (Fig. 19). The antennae have 16 constricted joints, the third joint the longest. The proboscis is as long as the head. The palpi have five segments of which the last segment is the longest. It is a carrier of Pappataci fever.

Other members of the genus will carry Pappataci fever i.e. *Phlebotomus minutus* and *P. perniciosus*. A general description of one will apply to all but there are certain specific differences in the wing venation, lengths of palpi, etc. According to Franc the forms found in America differ rather markedly from the Old World forms.

CHAPTER VII

SUBORDER ORTHORRHAPHA

SECTION BRACHYCERA HOMODACTYLA

These flies because of their blood-sucking habits are either actual or potential carriers of disease among man and the lower animals. Of the families mentioned in the key, Tabanidae is by far the most important as to it belong many blood-sucking flies variously called horse flies, gad flies, deer flies, breeze flies, mangrove flies, green head flies etc., which have a wide distribution. Many of them are vicious biters and a source of great annoyance to man and animals, but, up to the present, only a few of them are known to be actual vectors of disease. The males do not bite; they subsist on the juices of fruits and flowers.

Family Tabanidae

Adult. Anatomy. (Figs. 20 and 21).—In general the adult Tabanidae may be described as having a *head* as wide or wider than the thorax, convex in front, with very large brilliantly colored *eyes* which almost meet in the male (holoptic) but are much wider apart in the female (dichoptic). The eyes may be bare (glabrous) or hairy (pilose). The *antennae* are three segmented, the third or last joint having from four to eight annuli or rings. To definitely observe this point in a given species it may be necessary to clear and mount the antenna. There is no *arista*. The *proboscis* varies in length in the different genera. It may be very long or short. It is comprised of a *labrum-epipharynx* and a *hypopharynx*, which when apposed form the blood channel. There are also two *maxillae* with their *two-segmented palpi*, and two *mandibles*. The maxillae which are serrate and the mandibles which are blade-like, serve as the weapons to make and enlarge the gash in the skin from which the blood is sucked. These organs lie in the groove of a thick *labium* which terminates in *labellae* containing a *pseudotracheal membrane* similar to that found in the nonbiting, sucking Muscoidean flies. The mouth parts are

not inserted as deeply into the integument as are those of the mosquito but the blood is drawn by means of the gashes or incisions made

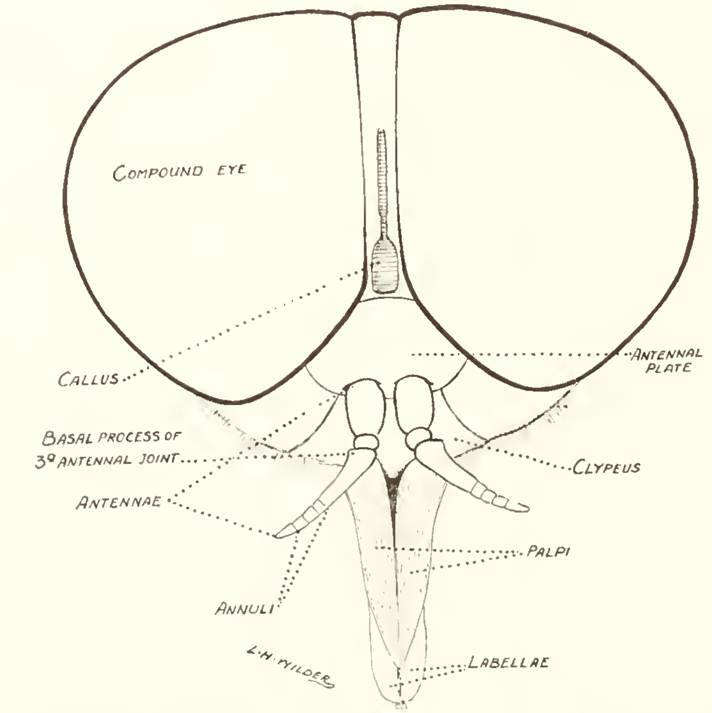

FIG. 20.—Head of *Tabanus* (*T. striatus*), front view, to show anatomical parts.

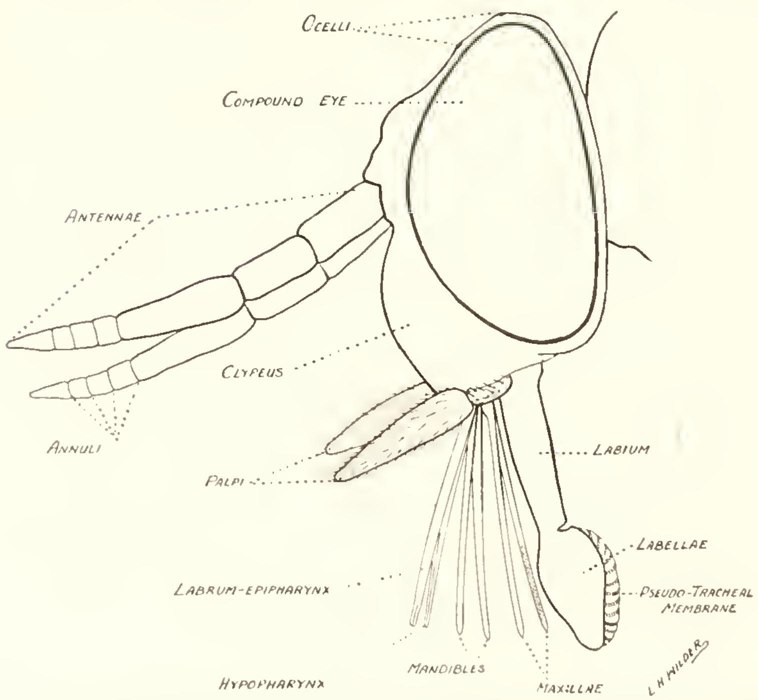

FIG. 21.—Head of *Chrysops* (*C. discalis*), side view showing mouth parts.

in the skin. In some species of Tabanidae there are shiny reddish or brown areas between the eyes known as *calli*. The *wings* (Figs.

22 and 23) diverge at the tips; they may be *mottled* and they have *five posterior cells*, an elongate *basal cell* and a large *discal cell*. The third longitudinal vein is bifurcate. The *legs* are large and strong.

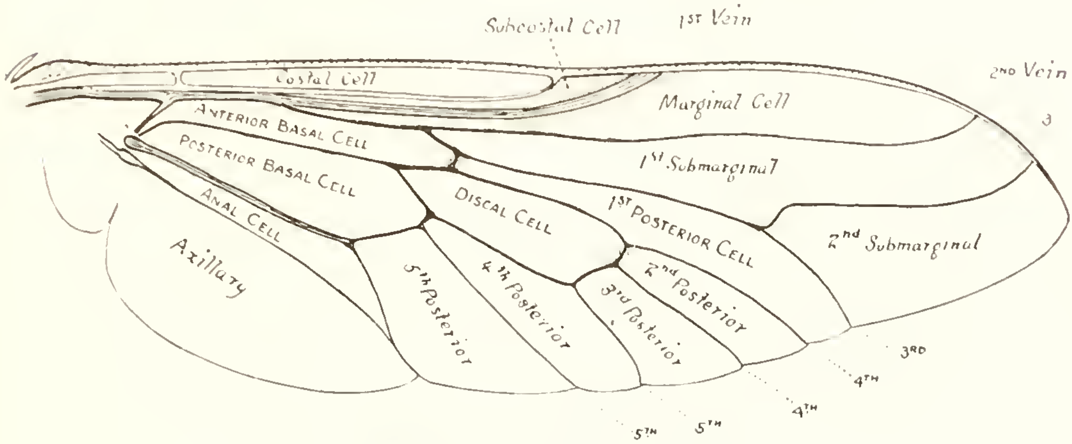

FIG. 22.—Wing of *Tabanus* (*T. molestus*).

The body is not highly colored but brown, whitish or yellowish with perhaps markings on the abdomen. The thorax and abdomen contain hairs but no bristles. The empodium is pulvilliform (Fig. 24).

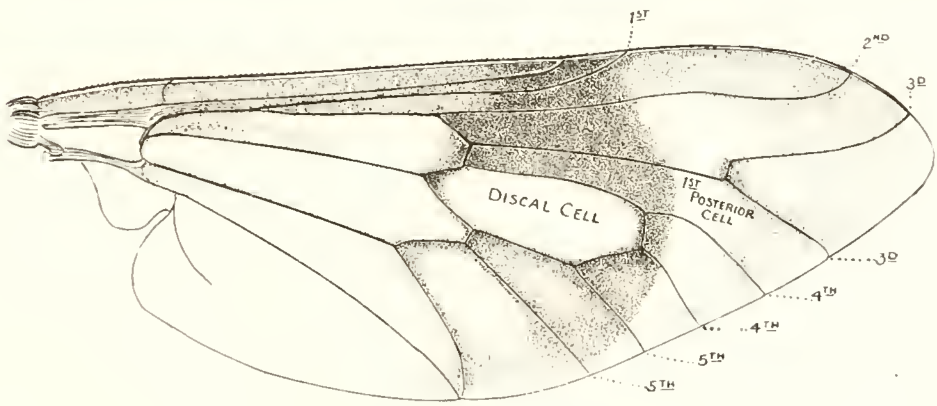

FIG. 23.—Wing *Chrysops* (*C. discalis*).

The Alimentary Canal.—The *oesophagus* is short. It begins at the pharynx in the head and runs through the brain and the neck to enter the thorax where it branches. One branch enters the midgut through the proventriculus. The other branch traverses the thorax to enter the crop. The *crop* is a thin walled bilobed sac analagous to the oesophageal diverticula of other Diptera, but apparently not the same in function as it is not clear that it acts as a food reservoir. The *proventriculus* is a long flattened tube traversing the thorax. At its anterior end it is broadened but posteriorly becomes narrow and merges into the beginning of the mid gut. The *midgut* or *stomach* is

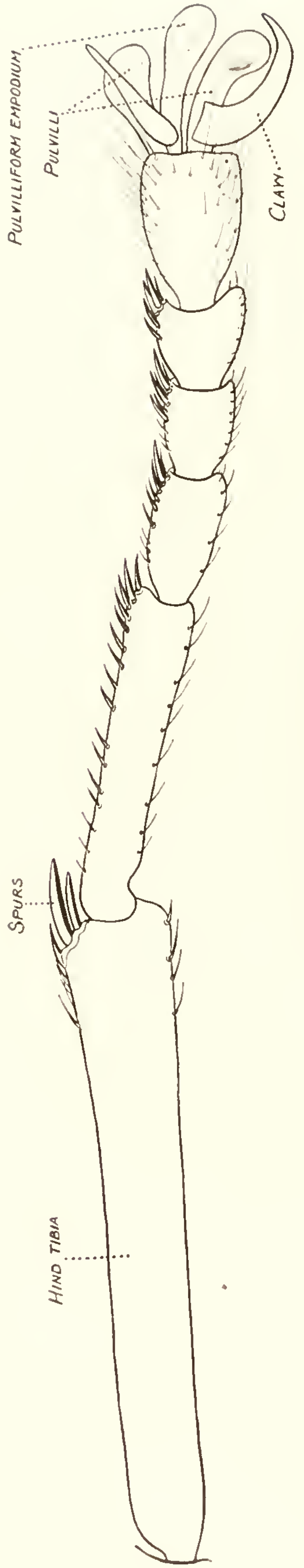

Fig. 24.—Hind leg of *Chrysops*.

dilated with its narrowest end anteriorly. It is located within the abdomen. The *hindgut* is divisible into two parts an upper part, the *ileum*, narrow and convoluted, and a lower part, the *colon*, wider and straight. It terminates in a pear shaped *rectum* in the walls of which are *six rectal glands* or papillae. The *Malpighian tubules*, four in number, empty into the intestines at the junction of the mid and hind gut. They lie coiled and twisted within the abdomen.

The *salivary glands* are long and tubular, lying in the lower part of the thorax on each side of the proventriculus and extending into the abdomen where their ends are somewhat dilated. The Tabanidae, like the Muscidae with a pseudotracheal membrane, have *labial salivary glands* located in the proboscis.

Egg.—The eggs of this family are spindle shaped and are laid in large masses, raft or flask shaped, on the leaves and stems of water plants or plants growing in marshy ground or in stagnant or moving water. In some species the eggs are deposited on rocks above the water level of streams. The newly hatched larvae drop into the water and immediately bury into the mud.

Larva.—The larvae are aquatic or semi-aquatic breathing by means of a caudal siphon. They are spindle shaped and have protuberances on the segments ventrally or encircling them. They live in the wet mud, feed on small animal organisms and also destroy each other. When ready to pupate they tunnel into the earth above the water level and are found some distance away from the water just below the surface of the ground.

Pupa. The pupae are free and provided with rings of spines projecting backward.

Method of Control. Kerosene spread on the surface of bodies of water frequented by this fly, is said to be efficacious in reducing their numbers.

CLASSIFICATION

The Family Tabanidae is divided into two subfamilies Tabaninae and Pangoninae, the latter having spurs on the hind tibiae (Fig. 24) and usually ocelli. The Subfamily Pangoninae is important because it contains the Genus *Chrysops* Meigen, members of which are known to transmit Loa loa and tuleraemia or deer fly fever. The former is carried by *Chrysops dimidiata* and *Chrysops silacea*, West African species, the latter may be transmitted by *Chrysops discalis* in the United States.

Key to Some of the Genera in the Family Tabanidae

1. Hind tibiae without spurs at the tip; ocelli absent.
   Subfamily *Tabaninae* 2
   Hind tibiae armed with spurs at the tip; ocelli usually present.
   Subfamily *Pangoninae* 6
2. Thorax and abdomen with irredescent tomentum .... *Lepidoselaga*
   Thorax and abdomen without irredescent tomentum 3
3. Third segment of antenna with well developed basal process; wings hyaline or clouded .... *Tabanus*
   Third segment of antenna without basal process or the process rudimentary .. 4
4. Antenna extremely slender first joint elongate .... *Hippocentrum*
   Antenna not especially slender nor first joint especially elongate 5
5. Front of female as broad as long; callus transverse .... *Haematopota*
   Front of female narrow .... *Diachlorus*
6. Third segment of antenna with five annuli the first of which is much longer than any of the following; proboscis short 7
   Third segment of antenna with seven or eight annuli, the first of which is but little longer than the following ones; proboscis long or short 8
7. Antenna longer than the head; second segment as long as or but little shorter than the first; wings banded (Page 58) .... *Chrysops*
   Antenna shorter than the head; second segment about half as long as the first .... *Silvius*
8. Proboscis long often projected horizontally 9
   Proboscis short, directed downwards; front of female broad, callus large . 10
9. Proboscis little longer than the head; palpi large and thick .... *Cadicera*
   Proboscis usually much longer than head, often longer than the body; front of female narrow .... *Pangonia*

10. Upper corner of eye in female terminating in an acute angle; wings darkened basally . . . . *Goniops*
Eye of female not acutely angulated above; wings hyaline . . . . . . *patolestes*

Genus Chrysops

This genus may be distinguished from other members of the subfamily Pangoninae by the relatively short proboscis and the long antennae, longer than the head. There are three ocelli (simple eyes) in addition to the two compound eyes which are golden green and marked with purplish spots. The beautiful coloration can only be observed in fresh specimens. The wings show a conspicuous dark band and are kept half open when at rest.

The eggs of *Chrysops* are deposited upright in a single layer, on leaves and stems of plants above or near water, or on exposed rocks in streams.

The larvae and pupae resemble those of Tabanus except that in the larvae the last antennal segment is longer than the segment which immediately preceeds it, while in the pupae the antennae project beyond the head.

CHRYSOPS DISCALIS (Williston) (FIG. 25)

This is an American species which has been implicated in the spread of tularaemia in Utah. (Chap. XXXI.) The fly has been

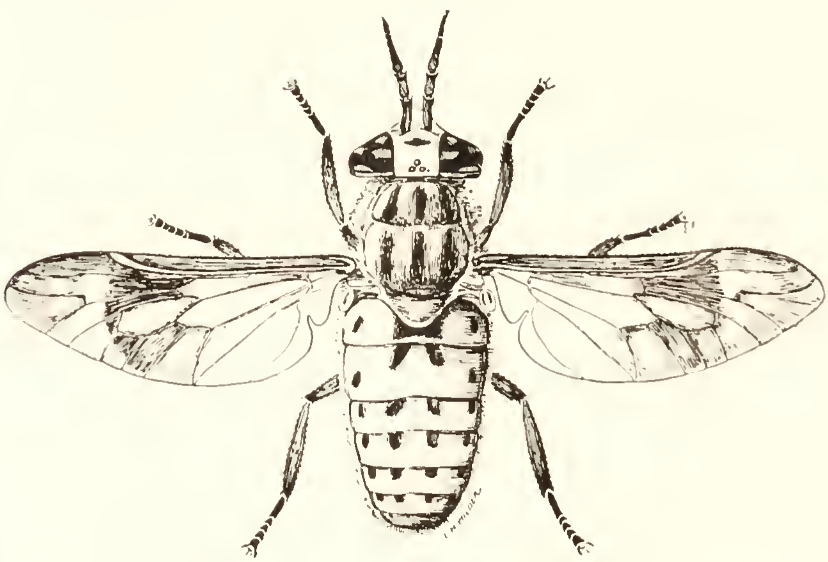

FIG. 25.—*Chrysops discalis.* (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology" 7th. Edition.)

reported from Utah, Idaho, Montana, Wyoming and Colorado. It is rather large, 10 to 11 mm. long, with a prominent hyaline space in

the discal cell. (Fig. 23.) In the female there are various sized hyaline spots in all of the wing cells except the costal, marginal and fourth posterior. The axillary cell is almost entirely hyaline. The ventral surface of the abdomen is gray with three rows of black spots. The male is much darker than the female.

CHRYSOPS FULVASTER (Osten Sacken)

This is another American species abundant over a number of Western states. It may be distinguished readily from *C. discalis* by the enlarged first antennal segment. The female but not the male may have a hyaline spot in the discal cell as in *C. discalis*.

Family Leptidae

A few members of this family have been reported as biting man, one, *Symphoromyia grisea* Meigen, in Italy, and another, *Symphoromyia hirta* Johnson, in Colorado. The latter is said to inflict painful bites throughout the day in sunny weather.

SECTION BRACHYCERA HETERODACTYLA

The tribe is not of great importance from the standpoint of preventive medicine as few of its members bite man nor are their usual habits such that they would become a menace.

One of the Phoridae, *Phora femorata* is found in houses occasionally. Another, *Aphiochaeta ferruginea* of India, West Indies and Central America, has been reported as a cause of intestinal and cutaneous myiasis. One of the Scenoponidae, *Scenopinus fenestralis* or "window fly" is a household fly which is not a menace to health.

FIG. 26.—Wing of *Apiochaeta* (Phoridae). (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology" 7th. Edition.)

Members of the family Asilidae have been called "robber flies" because they prey on adult insects frequently other flies.

CHAPTER VIII

SUBORDER CYCLORRHAPHA

SECTION ASCHIZA

Description.—This section is of little practical importance in preventive medicine. In the Aschiza a lunula may be seen but the ptilinal suture is absent; the third segment of the antennae is simple and has an arista which is either terminal or dorsal; the third vein is never forked; there are never more than three complete posterior cells and the empodium is never pulvilliform.

Family Syrphidae

Larvae of *Eristalis tenax* (Drone fly) (Fig. 27) a member of the family Syrphidae, have been reported as causing intestinal myiasis, in some instances with severe symptoms. The larvae of this fly are known as "rat tailed" larvae because of their long breathing tube. Eggs are laid in liquid manure or in filthy liquids in chambers, privies, highly polluted ditch water and the like. The family Syrphidae is characterized by the presence of a spurious vein simulating a longitudinal vein and caused by a thickening of the membrane of the wing between the third and fourth longitudinal veins. The antennal grooves are absent.

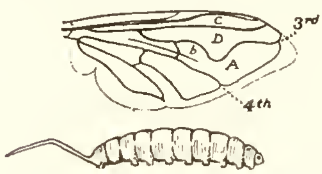

FIG. 27.—Wing and rat-tail larva of *Eristalis* (Syrphidae). (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology" 7th. Edition.)

SECTION SCHIZOPHORA

The section Schizophora is of great importance in preventive medicine because it contains a number of flies, of which, some bite, some like the house fly carry disease mechanically, while the larvae of some may cause myiasis in one or another of its forms.

Description.—In the Schizophora the lunula is distinct and the frontal suture is present; the antennae are three jointed and simple; the arista may be plumose, pectinate or bare and is placed dorsally;

none of the longitudinal veins is forked and there are not more than three posterior cells.

The Group is divided into two tribes, Acalyptratae and Calyptratae. In the former the squamae are small at times rudimentary; the thorax has no complete transverse suture and the subcostal vein is often small or vestigial.

Muscoidea Acalyptratae

The family Sepsidae includes the cheese fly, *Piophila casei* Linnaeus, which may cause intestinal myiasis, and the dung fly *Sepsis violacea*, which may be found in houses.

Microneurium funicola de Meijere of the family Oscinidae is a small fly of Java and Ceylon which hovers in front of the eyes and is suspected of carrying the Koch-Weeks bacillus. Several species of *Hippelates* found in the Southern United States dart at eyes and other parts of the body in search of perspiration.

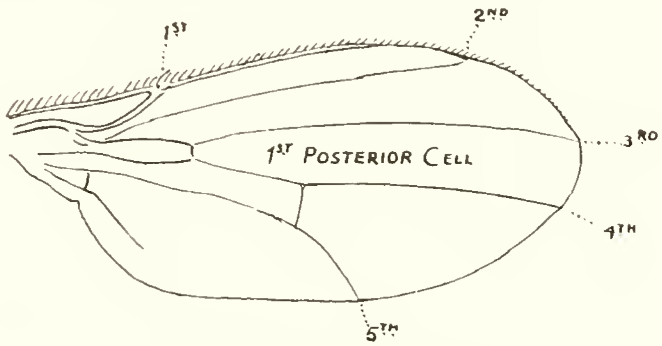

FIG. 28.—Wing of *Drosophila*.

The Family Drosophilidae contains the Pomace flies, which breed largely in decaying fruit. *Drosophila melanogaster* (= *ampelophila*) is common. It may be attracted by excrement and therefore might carry certain diseases of the intestinal type. Eggs are deposited on overripe fruit in which the larvae develope. The larva is very small and has projecting from the tail end two small fleshy processes carrying the stigmal plates. No doubt these larvae are frequently taken into the alimentary canal of man.

The Family Borboridae contains a small fly (*Borborus equinus*) which may enter houses. It breeds in dung and other refuse.

CHAPTER IX

SUBORDER CYCLORRHAPHA (CONT'D)

MUSCOIDEA CALYPTRATAE

In the Calyptratae the squamae are well developed; the thorax has a complete transverse suture and the auxiliary vein is normal. These are collectively known as the Muscoidean flies included among which are such important Families as *Muscidae*, *Sarcophagidae* and *Calliphoridae*. It is therefore advisable before going further to give some attention to their anatomy.

Adult Anatomy. The Head. (Fig. 29).—For the purpose of more easily locating and describing the various parts and bristles of the head it is convenient to regard it as having a superior and inferior region, two lateral regions and an anterior and posterior region.

The superior region, the highest part of the head, is known as the *vertex*. Here are located the simple eyes or *ocelli*, usually three in number. They are placed in a definite triangular space the *ocellar triangle* or *plate*. The bristles arising from this plate are called the *ocellar bristles* of which there are two groups the *greater* and *lesser ocellars*. The former are a pair of bristles arising just back of the most anterior ocellus. They diverge and point forward. The latter consist of a varying number of pairs of bristles extending backward from the insertion of the greater ocellars. The last pair are sometimes called the *post vertical bristles*.

At the vertex of the head between the ocellar triangle and the eye more or less behind its inner and upper corner are four bristles, two on each side. The inner pair are known as the *inner vertical* bristles. These are usually the larger of the two pairs and are erect or convergent. The outer pair, those nearest the eye, are the *outer verticals* and are erect or divergent.

The anterior region of the head has been divided into two parts an upper and a lower. The upper part is known as the *front* or *frons* and is that area lying between the eyes and limited above by the ocellar triangle and below by the arch of the ptilinal suture.

The rest of the anterior region extending downward from the front to the cheeks laterally and to the lower margin of the head in the middle line, is the *face*.

The area occupying the middle of the front between the ocellar triangle and the arch of the ptilinal suture is known as the *frontalia*.

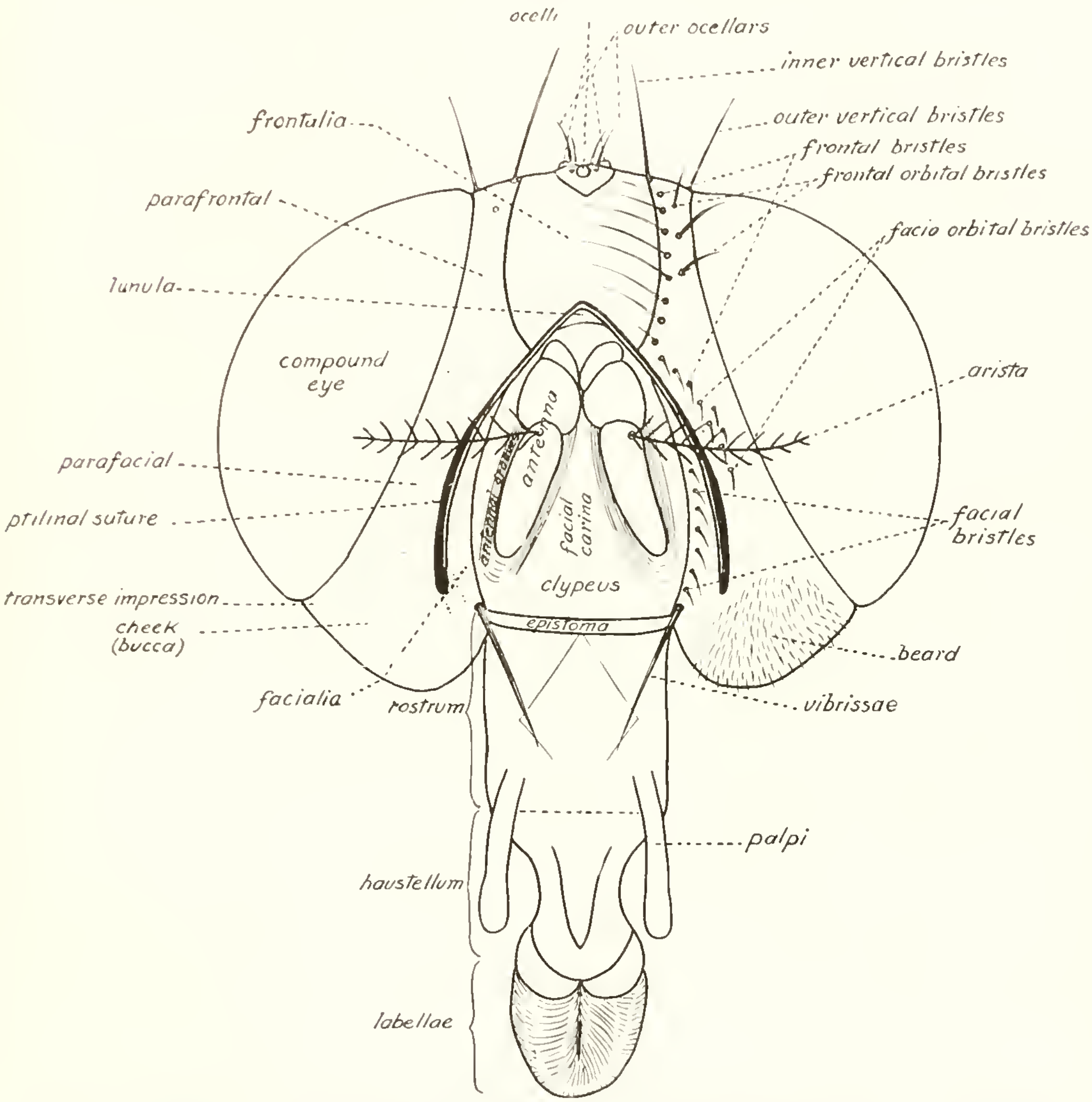

FIG. 29.—Head, front view, of a Muscoid fly to show anatomical parts. (Semidiagrammatic.)

On either side of the frontalia i.e. between it and the compound eyes are the *parafrontals* or *genovertical plates* which extend upward over the vertex to the epicephalon of the posterior region, and extend downward to a level somewhat below the roots of the antennae to become continuous with the parafacial areas. A row of bristles extending downward on either side of the frontalia are known as the *frontal* bristles or *frontals*. Outside of the frontal row, that is

between the frontals and the eye and anterior to the vertical bristles, may be seen one or more bristles which are termed the *fronto-orbitals*. Other bristles lower down and not quite in line with the fronto-orbitals are called the *lower fronto-orbitals*.

The *ptilinal suture* has been mentioned several times and as it is a very important and characteristic feature of the Muscoid flies it would be well to study it before going on to a description of the face. This suture arches over the base of the antennae extending downward on each side at times almost to the lower border of the head. It has the shape of an inverted U. It is sometimes called the *frontal suture* or *frontal fissure*, and it is the scar resulting from the closure of the fissure through which the ptilinal sac was thrust to force the cap off of the pupal case and thus permit the fully developed fly to emerge.

The ptilinal suture marks off an area in the middle of the face which is known as the *ptilinal area*. In this area lie the *three-jointed antennae* in the *antennal grooves* or *foveae*. They are separated from the lateral arms of the ptilinal suture by the *facialia*, distinct ridges which extend downward on either side to the lower margin of the head. The lower end is prominent and is called the *vibrissal angle*. The angle of each side has arising from it a prominent bristle—*the vibrissa*. Running along the facialia above the vibrissae are the *facial bristles*. The lower median portion of the ptilinal area is the *clypeus* or *facial plate*. This may extend upward as a ridge between the antennae. Such a ridge is known as the *facial carina*. The clypeus is limited below by the anterior border of the epistoma which surrounds the *epistomal orifice* located in the inferior region of the head. It is through this orifice that the mouth parts are projected.

Just above the roots of the antennae and bounded above by the arch of the ptilinal suture is a small oval or crecentic depression, the *frontal lunule* or *lunula* and between the roots of the antennae is a small plate known as the *antennal plate*.

The area on the face between the lateral arms of the ptilinal suture and the eye is the *parafacial* area or *gena* as it is also called. It is limited below by the transverse impression and above becomes continuous with the parafrontal area. Bristles arising from it are called the *facio-orbital bristles*.

The *transverse impression* is a more or less distinct depression which begins at the ventral arm of the ptilinal suture, runs across the face and along the lower margin of the eye to its posterior or occipi-

tal border. The *cheek* is that area between the lower border of the eye and the oral margin. It is limited by the occiput behind and in front merges into the face. Hairs arising from it and from the lower border of the occiput comprise the *beard*. The term *bucca* is not quite synonymous with cheek for the bucca is an area below the transverse impression. under the eye, extending downward to the epistomal orifice and backward to the great foramen.

The posterior region of the head, the *occiput*, contains the *occipital* or *great central foramen* into which is inserted the neck. The area above the foramen which is formed of a ridge-like sclerite seemingly a continuation of the parafrontals, is called the *epicephalon* or *parafrontal-occipital ridge*. The area below the foramen is the *metacephalon* which is outlined by a distinct suture extending from the foramen outward and downward on either side. Laterally the area is known as the *paracephalon* or *paracephalic plates*. A pair of bristles placed high up and back of the verticals are known as the *occipito-centrals* while the small bristles in a row along the occipital border of the eye are called the *cilia of the posterior orbit*, the *orbit* being the narrow space immediately contiguous to the eyes.

The lateral portion of the head is occupied by the eyes and cheeks.

The Proboscis.—The mouth parts are adapted to biting and sucking or to suction only. In the latter case the proboscis of the house fly may be taken as the type. (Fig. 30.) In those Muscoids which suck only and which are of importance in Preventive Medicine —the nonbiting Muscidae, the Sarcophagidae, the Calliphoridae etc.— the proboscis is built on the same general principles only differing in the details of construction.

The proboscis is divided into a proximal part, the *rostrum;* a middle part, the *haustellum;* and a distal part the *labellae*.

The Rostrum.—The rostrum contains the buccal cavity and the aspiratory pharynx together with the muscles which operate it, and is that part of the sucking apparatus which in insects like mosquitoes, horse flies, fleas etc. is permanently located within the head cavity. In the house fly however it is capable of being extruded from and drawn back into the head at will. The overlying integument is attached above to the margins of the epistomal orifice and is continuous below with the integument covering the haustellum. In the accompanying figures to illustrate the mouth parts, the softer tissues, muscles, integument and the like, have been dissolved out with caustic leaving only the chitinous structures.

The most prominent structure in the rostrum is the *fulcrum* which in shape has been likened to a Spanish stirrup iron. It serves as a protection and gives attachment to the muscles which operate the aspiratory pharynx. The fulcrum forms the posterior wall of the *aspiratory pharynx* which runs along its entire length. The anterior wall of the pharynx is composed of a thin chitinous plate

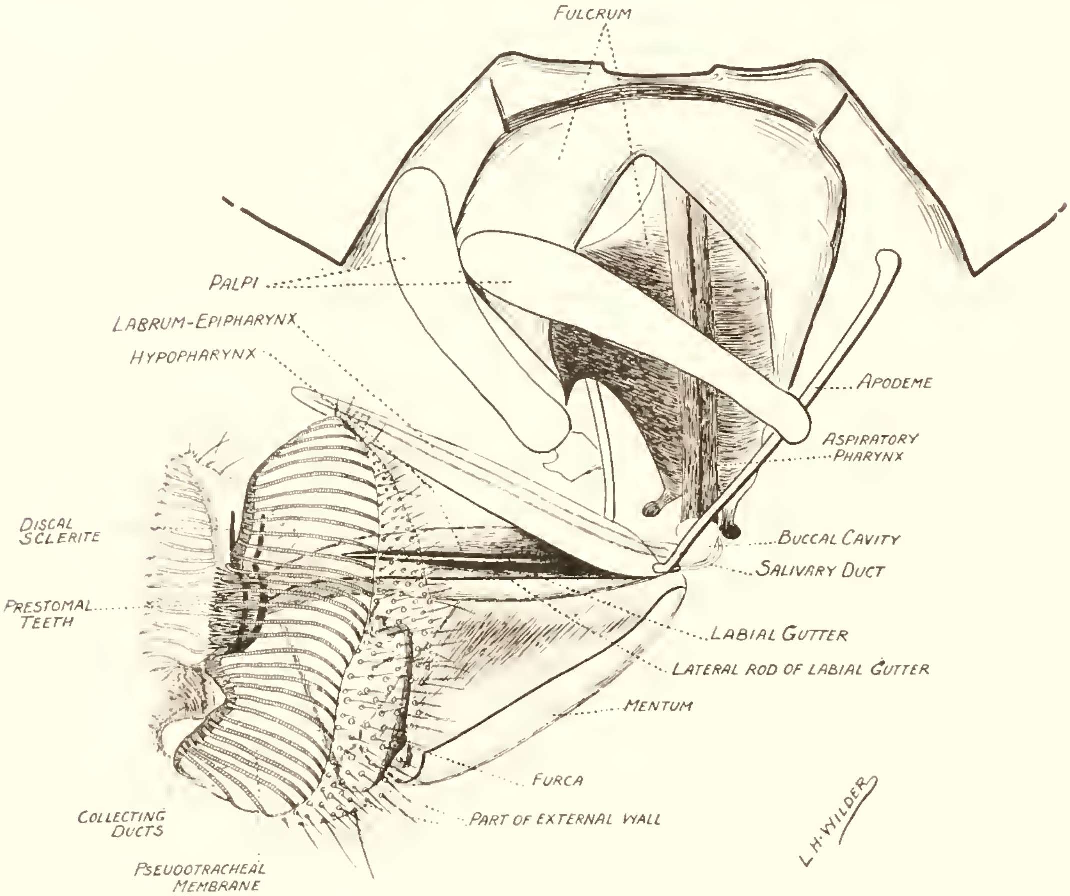

FIG. 30.—Proboscis of *Musca domestica.*

thickened down its centre to give better insertion to the muscles which operate it. The aspiratory pharynx begins below at the buccal cavity and ends above in the oesophagus.

The anterior wall of the *buccal cavity* and the distal extremity of the epipharynx are connected by a short membrane. A similar membraneous connection exists between the posterior wall of the buccal cavity and the hypopharynx. The buccal cavity is therefore in direct connection with the food canal in the haustellum. The *single jointed palpi* are not attached to the fulcrum but arise from the integument.

The Haustellum. The haustellum begins below the buccal cavity. It is the haustellum which is folded up under the head and entirely or partially concealed when the rostrum is drawn into the head. The haustellum is analogous to the fleshy labium of the mosquitoes and horse flies. Its posterior wall is composed of a plate of chitin, broad and slightly convex in its posterior aspect. This is the *mentum*. Anteriorly there is a long much narrower chitinous plate, convex in its posterior aspect forming a gutter—the *labial gutter*—in which rest the labrum-epipharynx and the hypopharynx. The mentum and labial gutter are connected by membranous tissue and between them are the soft parts, muscles, labial salivary gland etc. The gutter is thickened at each edge forming *the lateral rods*, which articulate distally with the discal sclerite. The *labrum* and *epipharynx* are closely attached to each other and freely movable and when apposed to the *hypopharynx* which lies beneath them, form a channel through which the fluid food passes when sucked up by the action of the aspiratory pharynx. The hypopharynx is not freely movable but is attached to the labial gutter throughout most of its length. It is channeled to carry the salivary juice.

On each side of the proximal end of the labrum-epipharynx there is articulated a chitinous rod—*apodeme*—which passes upward into the rostrum outside of the fulcrum. The apodemes serve for the attachment of muscles which are concerned with the movements of the haustellum and more particularly the labrum-epipharynx.

The Labellae.—The labellae begin at the *discal sclerite*. This is a somewhat V-shaped slender piece of chitin articulating about the centre of each of its arms with the lateral rods of the labial gutter at their distal extremities. It surrounds the *mouth* or *stoma* into which empty the large ducts which collect the fluid food from the smaller channels in the *pseudotracheal membrane*,—the most conspicuous structure in the labellae. Surrounding the mouth and arising from the discal sclerite are a number of very small weak teeth known as the *prestomal teeth*. These are not sufficiently stout to abrade the skin but in the biting Muscidae are greatly modified so that they are adapted to cutting as will be seen later on. The labellae are articulated to the haustellum through the discal sclerite above and another sclerite, the *furca*, below. These two articulations permit of the free movement of the labellae.

This sucking proboscis has been evolved from the proboscis of the biting Muscoidean flies. Following the evolution backwards one should next study the proboscis of *Philaematomyia*, a genus not found in the United States. (Fig. 31.) In this Genus the similarity of parts as compared to the proboscis of the house fly can be readily seen but there is a marked change in size, shape and density which adds rigidity and increases strength, for at least one member of this Genus can actually scarify the skin and draw blood.

As in *Musca* the rostrum can be drawn into the head and the haustellum folded up beneath but the latter has become narrower

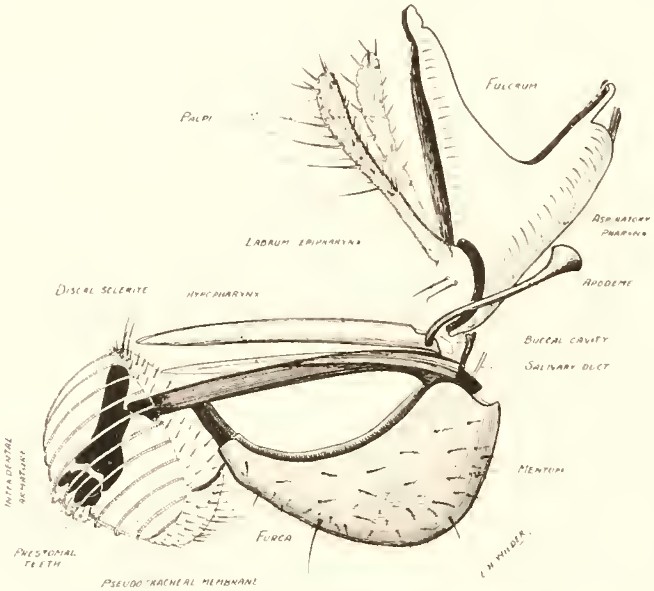

Fig. 31.—Proboscis of *Philaematomyia*.

and more prominent posteriorly because of the greater convexity and deepening of the mentum. The labial gutter has become narrower and the labial rods thickened and strengthened. The discal sclerite is markedly thickened and its articulation with the lateral rods much firmer. The prestomal teeth have been reduced in numbers to about eight and each is increased in size and strength. Between them may be seen a number of very small blade-like processes, the interdental armature. The pseudotracheal membrane is reduced as compared to *Musca* but functions in the same way collecting the blood or serum which exudes following the scarifying action of the prestomal teeth.

The next example of a proboscis forming a true biting apparatus may be learned from a study of the mouth parts of *Stomoxys*. (Fig. 32.)

Like Musca the rostrum can be drawn into the head but the haustellum has become greatly elongated and highly chitinized so that it sticks out prominently in front of the head when the proboscis is at rest. The labellae are greatly reduced in size and the pseudotracheal membrane has practically disappeared. A closer study

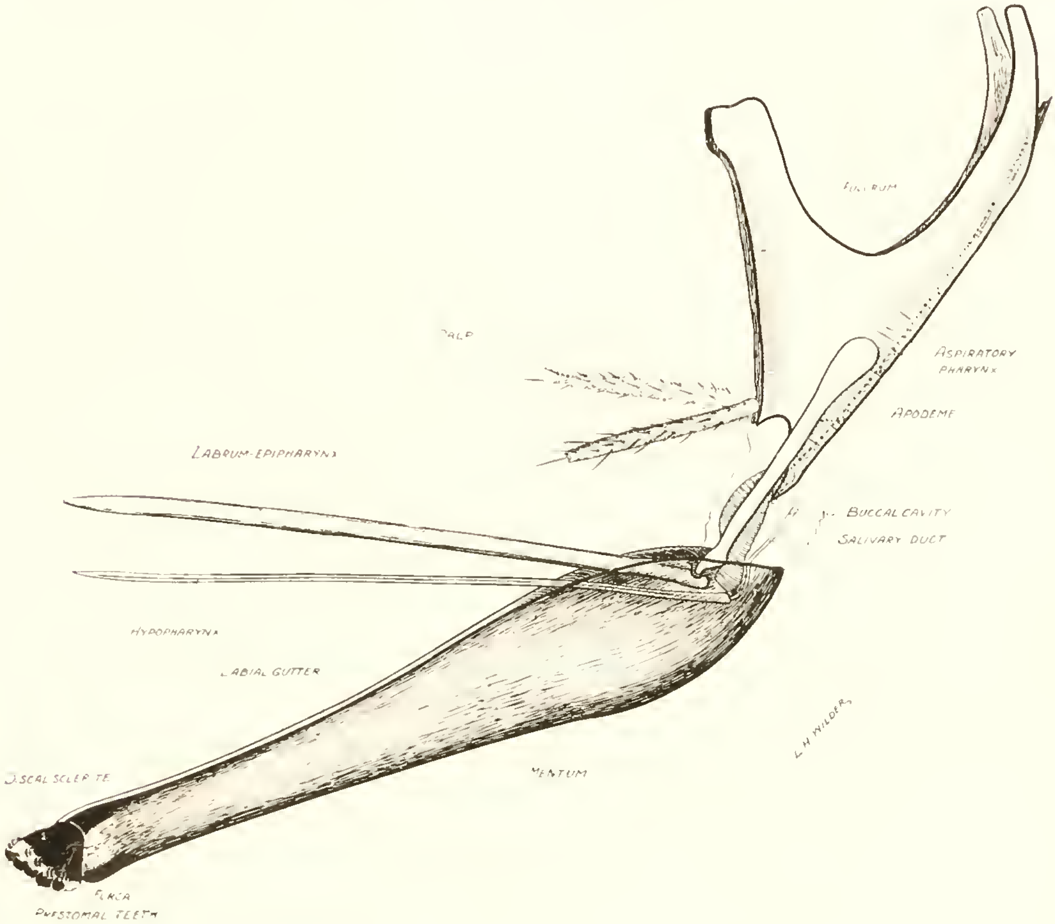

FIG. 32.—Proboscis of *Stomoxys calcitrans*.

shows that the mentum is narrowed and elongated, tapering towards the distal extremity and bulging towards the proximal end. It and the labial gutter are closely connected by a narrow strip of membrane. The hypopharynx is freely movable. The discal sclerite is powerfully built forming a strong collar around the stoma. The prestomal teeth are sharp pointed cutting teeth each one having a secondary cutting point towards the base. They are united to each other at their bases where they are attached to the discal sclerite and between them may be seen the interdental armature made up of tiny leaf-like blades. In addition there is a series of very small rod-like processes, a pair for each tooth, which are probably sensory in function.

In biting the prestomal teeth are everted and partially rotated which operation acting repeatedly and with great rapidity bores a way into the skin.

Except for the Genus *Philaematomyia* which has already been mentioned the proboscis of all biting Muscidae is constructed on the same general principle but differs in details in the various Genera. The proboscis of Glossina is probably the most highly specialized of the entire group.

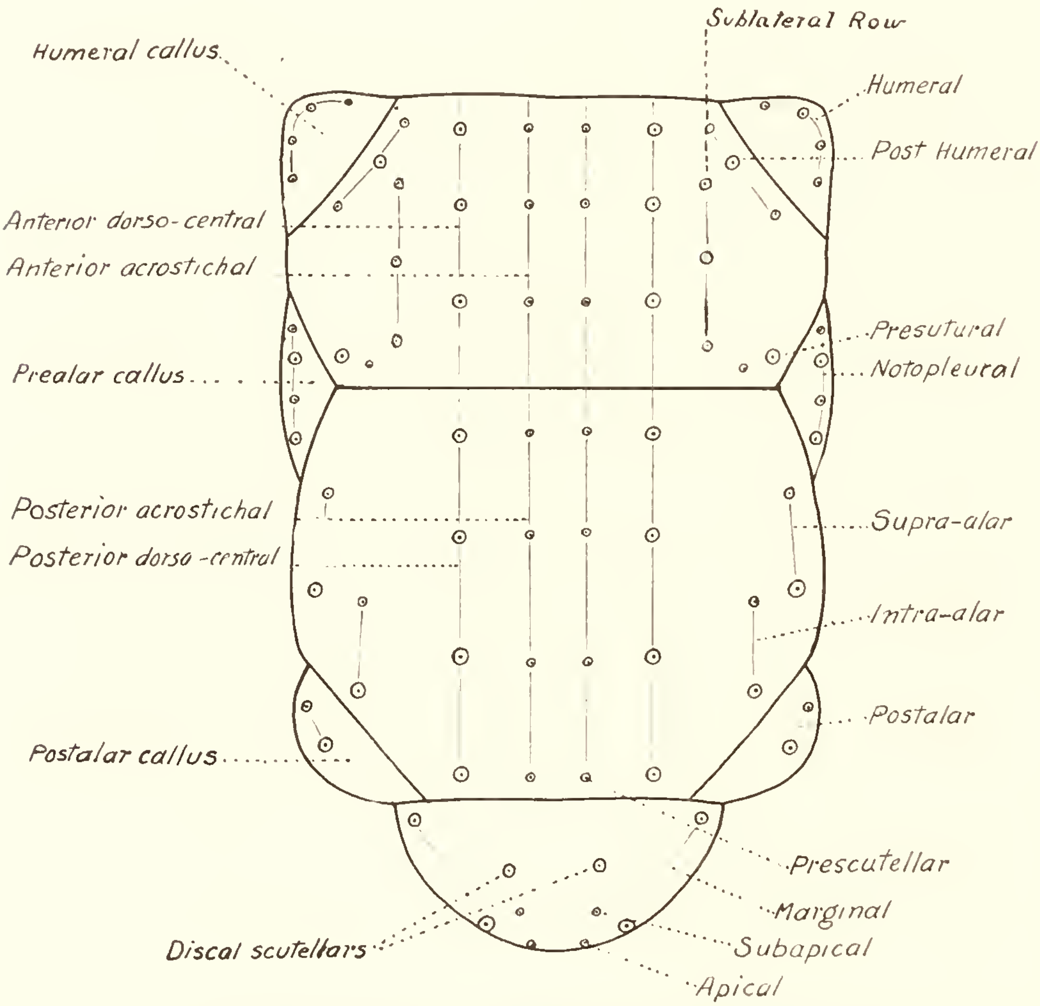

FIG. 33.—Dorsal view of thorax of fly of the Muscid type to show grouping of macrochaetae (bristles) (Semidiagrammatic).

The Thorax. (Figs. 33 and 34).—It seems unnecessary to attempt a detailed description of the thorax as a study of the illustrations will prove much more satisfactory. Suffice it to say that the *mesothorax* is by far the largest segment of the thorax. Dorsally it is divided by a transverse linear impression, (a depressed line) the *transverse suture*, into an anterior and posterior portion, the *pre-*

scutum and *scutum* respectively. Posterior to the latter is the *scutellum*, more or less triangular shaped and marked off from the scutum by another transverse linear impression.

The *bristles* of the scutellum may be *margina* i.e. when they are borne on its edges. They may be *discal* when they are placed on the surface of the scutellum away from its margins. They may be *apical* when they are located at the tip of the scutellum and *subapical* if they are just anterior to the tip. When present, there is usually not more than a pair of either apicals or subapicals.

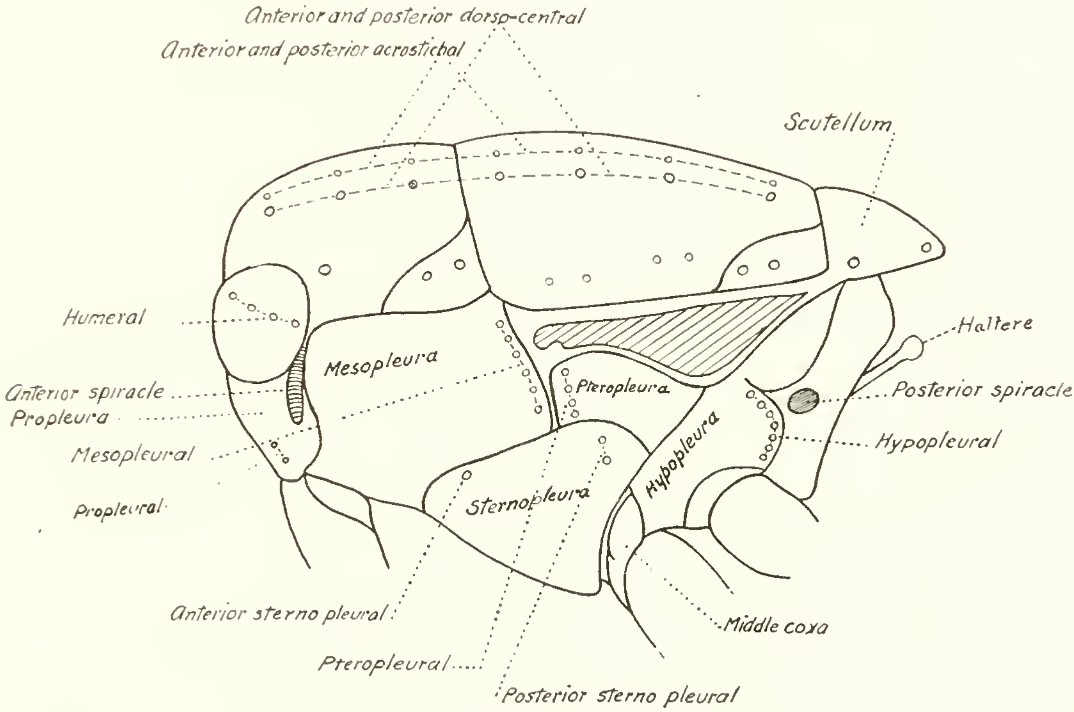

Fig. 34.—Lateral view of thorax of a Muscoidean fly to show bristles and other anatomical parts (Semidiagrammatic).

The Wings. (Fig. 35).—A few words in connection with the illustration will suffice. Particular attention should be paid to the *first posterior cell* which lies between the third and fourth longitudinal vein; the *discal cell* which is bounded by the fourth and fifth longitudinal veins and the posterior cross vein. The locations of the *basal cells* should be noted.

The *fourth longitudinal vein* should be studied with regard to its degree of angulation or bend and the degree to which it closes the first posterior cell. The point on the wing margin at which the *costal vein* ends should be noted. It will be remembered that unlike the costa of mosquitoes the costal vein in the flies under consideration does not extend all round the wing margin. The presence or

absence of the *auxiliary vein* should be noted. The *stem vein* should be studied. The stem vein is a thick vein toward the base of the wings which is the basal section of the first longitudinal vein and separated from the rest of the vein by a suture about opposite the humeral cross vein. It may carry a row of hairs when it is said to be *ciliated*. In some flies a *costal spine* is present. This is a stout bristle on the costal vein near the end of the auxiliary vein.

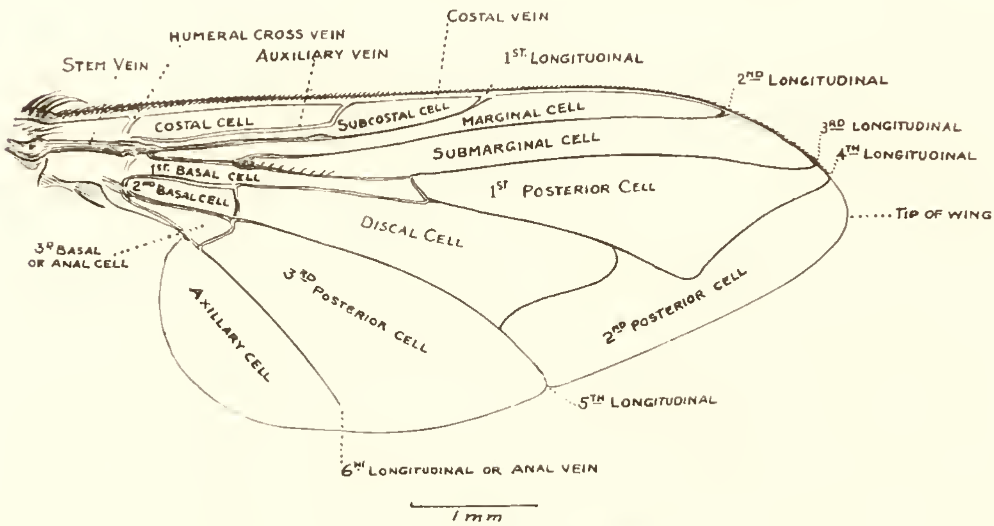

FIG. 35.—Wing of *Lucilia*.

The *squamae* (calypters) are a pair, an upper and a lower, of membraneous expansions from the root of the wing extending backward over the halteres. The squamae may be provided with a fringe of cilia. Two scales at the extreme base of the costa may be present in some flies and are known as the *epaulet* (tegula) and *subepaulet* (basicosta). The latter which is the outer is easily seen. The former may be so close to the body as to be seen only with difficulty. The vestiture and color of these may furnish valuable diagnostic points. The *subcostal sclerite* is a more or less triangular structure on the lower side of the wing at its base.

The Abdomen.—The number of segments that can be recognized as such externally varies considerably—from four or five to seven. The terminal segments, have been greatly modified to form structures concerned with reproduction that is, the *clasping organs* of the male and, in certain flies, the *ovipositor* of the female. The clasping organs (Fig. 48) have great taxonomic value as they differ in shape and size in the different species. The external genitalia of the female can not be used in differentiating species as they do not

posess distinctive characters. The extent of their development depends upon the breeding habits of the insect. The house fly for instance has an ovipositor made up of the last four segments of the abdomen forming a long narrow tube large enough to admit the passage of an egg. When in use it is thrust out of the body and directs the egg to a favorable location in the breeding material. When not in use it is drawn inside of the abdomen, one segment telescoping into the other. In those flies which give birth to a living larva the ovipositor may be very inconspicuous or may be no more than a mere slit at the end of the abdomen.

Bristles on the abdominal segments may be *marginal* or *discal*.

Alimentary Tract.—The *alimentary canal* is longer than that of the mosquitoes or Tabanidae because of the elongation of the *mid-gut* or *stomach*. There is no dilated portion as seen in the Orthorrhapha, but the capacity and absorptive surface are maintained if not increased by the greater length. A *proventriculus* serves as a valve between the fore-gut and the mid-gut. The *oesophagus* is short. It passes through the brain and the neck into the thorax where it is in communication with the proventriculus ventrally. Here the duct of the crop begins. The *crop* is a large thin walled sac which is filled when the fly is feeding, its contents being passed on slowly to the stomach. It lies beneath the stomach and when full occupies quite a large part of the abdomen.

A curious structure is the *peritrophic membrane*, a thin walled tube within the lumen of the mid- and hind-gut, having its origin at the proventriculus and terminating at the anus. There is thus an inner tube separating the contents of the gut from the epithelium lining the gut. It is in contact with the lining cells but is not attached to them. The *Malpighian tubes* empty into the alimentary canal at about the junction of the mid- with the hind-gut. These are four in number the two on each side emptying into the gut by a common duct. The *hind gut* is not elongated. It empties into the rectum which has four *rectal papillae*.

The *salivary glands* are found in the thorax extending into the abdomen. They are long and tubular, sometimes coiled, lying free in the body cavity (the haematocoele) bathed in the blood and at places in contact with the walls of the gut. The ducts from the two sides unite in the head to form a common duct which passes down the rostrum outside of and posterior to the fulcrum to become continuous with the salivary canal in the hypopharynx. In flies having a

pseudotracheal membrane, salivary glands are also located in the haustellum—the *labial salivary glands*. They are at its lower end lying near the anterior surface and empty on the internal or oral surface of the labellae.

The Larva. (Fig. 36).—The larva of the Muscoidean flies is an active, voracious, legless, wormlike creature, without a distinct head (acephalous). It is usually tapering, the small end being the anterior or head end while the posterior end is broad. From the anterior end project two dark hook-like processes, the *mandibles*, which are sometimes fused into one. Above these are two *papillae*. The second segment from the anterior end has on each side, projecting hand or fan-like structures with a varying number of terminal

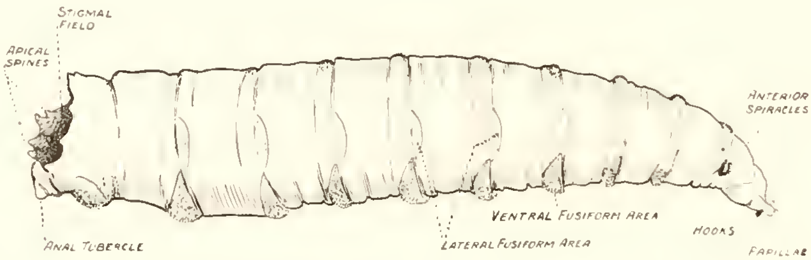

FIG. 36.—Larva of a Muscoidean fly to show certain parts used in identification.

divisions depending on the species. These are the *anterior spiracles*. The posterior, expanded end of the larva has on its posterior surface two chitinous plates each with three slits which vary in appearance according to the species and are only truly characteristic in fully matured larvae. They are the *stigmal plates*. The area carrying these plates may be sunken to form a pit and may or may not be surrounded by small *fleshy tubercles*. There may be a rounded protuberance or *button* at the base of each plate. The stigmal plates may also be observed in the pupal stage on the posterior end of the pupal case. The roughened areas to be seen on each segment are known as the *fusiform areas*. If ventrally situated, the *ventral fusiform areas;* if laterally, the *lateral fusiform areas*. The roughened area may extend completely around a segment. The roughening is due to the presence of minute spines or hooklets. Some larvae may be provided with spinous processes or fleshy processes other than the tubercles already mentioned.

The Pupa.—When fully grown the larva seeks a suitable place to pupate, usually loose soil. Here pupation takes place by a contrac-

tion and hardening of the larval skin producing a *puparium*. Such a pupa is said to be *coarctate*. The puparium is rounded, elongate-ovoid in shape and varies in color from dark gray or yellowish to dark brown. The pupa is quiescent and takes no food. The adult emerges from the pupal case through an opening made by forcing off a small circular cap in the head end.

Family Oestridae

The Oestridae are the "bot" or "warble" flies. They are very hairy and the mouth parts are rudimentary. The antennae are inserted into round pits.

Larvae of these flies are parasitic and spend their existence either under the skin, in the nasal or pharyngeal cavities or in the alimentary canal.

The following simple key will serve to distinguish the more important genera of the adult Oestridae

1. Fourth longitudinal vein straight or curved towards hind margin of wing; first posterior cell widely open; arista bare. . . . . *Gastrophilus*
   Fourth longitudinal vein bends towards anterior margin of wing; first posterior cell closed or narrowed. 2
2. Fourth longitudinal vein joins the 3rd. vein before the termination of the latter, entirely closing the 1st. posterior cell which is petiolate. *Oestrus*
   First posterior cell more or less narrowed but not closed. 3
3. Arista bare; proboscis rudimentary. . . . . *Hypoderma*
   Arista haired on upper side; proboscis well developed. 4
4. Tarsi slender not hairy. . . . . *Dermatobia*
   Tarsi broad, flattened, hairy. . . . . *Cuterebra*

Genus Hypoderma
(Warble flies)

Hypoderma bovis de Geer, may be mentioned as an example of dermal myiasis. The eggs of this fly are deposited on the skin of cattle attached to the hairs. Hatching requires about a week. It was thought that the larvae were then licked off and swallowed thus reaching the oesophagus where they remained a considerable time between the mucous and muscular coat, finally making their way to the subcutaneous tissue of the back where further growth took place producing lumps in the skin. Later investigators say

that the larvae perforate the skin near where the eggs are laid and then migrate to the subcutaneous tissues of the back, and that licking by the animal's tongue destroys more eggs than it introduces into the mouth. When ready to pupate the larva emerges through a small opening which it makes in the skin, and then drops to the ground which it enters to become a pupa. The pupal stage last from three to five weeks.

Another warble fly of cattle in the United States is *Hypoderma lineata* Vill.

The warble flies are of importance commercially. The presence of the larvae not only interferes with the nutrition of the animal but

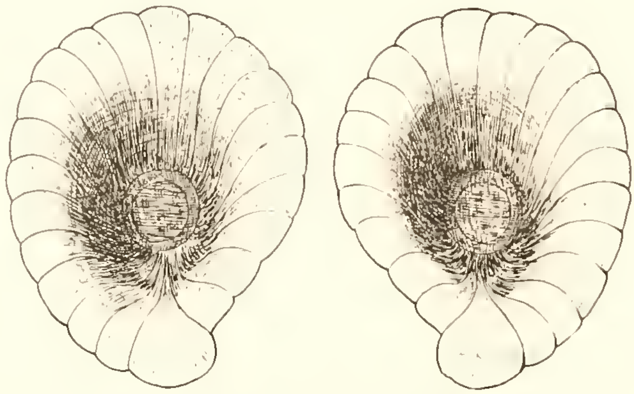

FIG. 37.—Stigmal plates of *Hypoderma bovis*.

causes the hide to become of inferior quality. At times great financial loss is sustained. Both species are reported for man.

A somewhat similar condition is occasionally observed in man giving rise to what has been called "creeping eruption" because the larva moves from place to place in the subcutaneous tissues. It is rare in the United States.

Other flies of the Genus *Cuterebra* attack squirrels and chipmunks (*C. emasculator*) and rabbits (*C. cuniculi*).

Genus Dermatobia

The larva of *Dermatobia hominis*, a fly of tropical and subtropical America, occassionally gains access to the subcutaneous tissues of man where it grows producing an abscess. When fully grown it emerges to pupate in the ground. It is thought that the eggs of this fly are attached to the ventral surface of the abdomen of a mosquito (Psorophora) or to other flies or to ticks and that when ready to

hatch they are left on the skin at the site of the wound made by the bite. The larva (Fig. 38) is pyriform in shape and the thoracic segments are armed with hook-like spines pointing backwards. These larvae are normally found in the subcutaneous tissue of lower animals and their presence in man is accidental, but in some regions not uncommon.

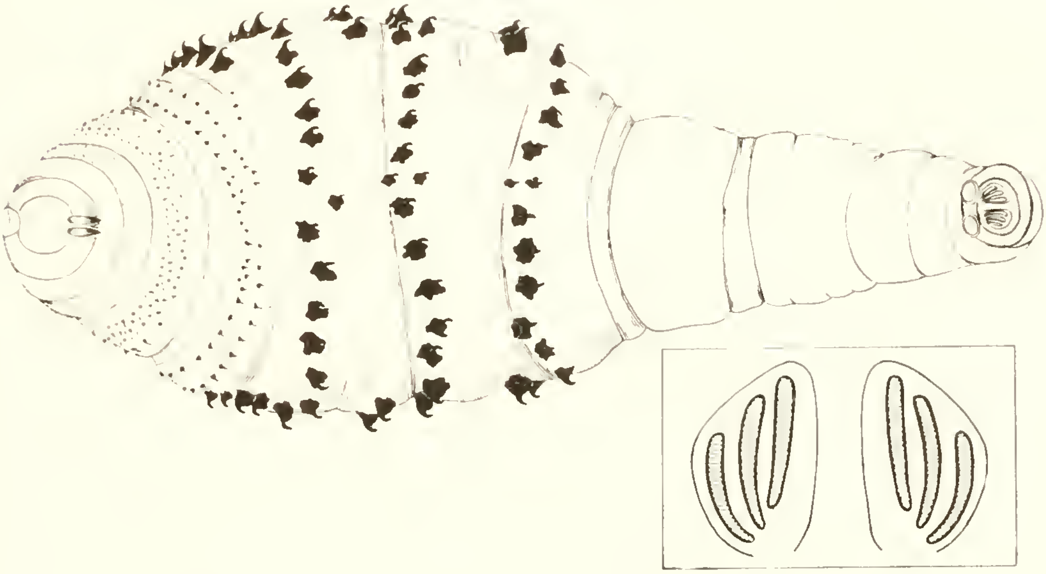

FIG. 38.—Larva and stigmal plates of *Dermatobia hominis*.

Genus Oestrus

(Bot flies)

As an example of nasal infestation mention may be made of *Oestrus ovis* Linnaeus, the sheep bot-fly, which lays its eggs around the nasal cavities of sheep. After hatching the larvae make their way into the nose and enter the sinuses where they grow attached to the mucous membrane. When fully grown they leave the nostrils and drop to the ground which they enter to become pupae. This larva has been found in the nasal cavities of man.

Genus Gastrophilus

(Bot flies)

As an example of intestinal myiasis mention may be made of *Gastrophilus equi* Fabricius, which deposits its eggs on the hairs of horses. Licking by the horses tongue keeps the eggs moist and hastens hatching. The larvae are licked off and swallowed thus enter-

ing the stomach where they attach themselves to its walls and grow. When fully grown they pass out of the intestines with the excrement, enter the ground and pupate. (Fig. 39.) *Gastrophilus hemorrhoidalis* Linnaeus is another horse bot fly. Both species are common in the United States.

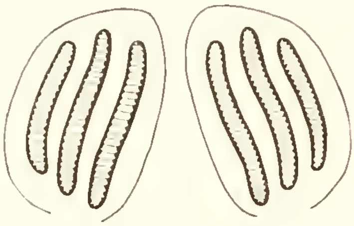

Fig. 39.—Stigmal plates of *Gastrophilus equi.*

A separate Family has been made for *Gastrophilus*, namely Gastrophilidae. It is here mentioned under the Oestridae because of its habits.

CHAPTER X

MUSCOIDEA CALYPTRATAE (CONTINUED)

FAMILY MUSCIDAE

Key to Some of the More Important Genera of the Muscidae

1. Proboscis completely retractile and capable of being flexed back under the head and completely or partially concealed; labellae well developed; haustellum not forming a conspicuous, elongated, tapering projection in front of the head (Figs. 30 & 31) 2

   Proboscis only partially retractile, not capable of being concealed under the head; labellae absent or vestigial; haustellum forming a conspicuous projection in front of the head (Fig. 32) 5

2. Proboscis capable of being only partially concealed under the head; mentum always plainly visible as a strongly convex, chitinous plate; minute examination shows that the prestomal teeth are not numerous, are thickened and elongated and arranged in one row, that the pseudotracheal membrane is present and functional and that the hypopharynx is free from the labial gutter (Fig. 31).

   Philaematomyia Austen, 1909 (Page 86)

   Proboscis capable of being entirely concealed under the head; mentum not prominent; minute examination shows that the prestomal teeth are numerous, weak and arranged in three rows, that the pseudotracheal membrane is well developed and that the hypopharynx is only partially free from the labial gutter 3

3. Dark grey to black flies, never metallic in color 4

   Thorax, abdomen, cheeks and vertex shining green, lustrous ....

   Cryptolucilia (Page 85)

4. Fourth longitudinal vein bends sharply; 1st. posterior cell almost closed (Fig. 40); thorax marked with four longitudinal stripes or bands (sometimes fewer) of about equal length .... *Musca* Linn (Page 80)

   Fourth longitudinal vein bends gradually; first posterior cell widely open (Fig. 41); thorax marked with two short, black stripes and two fainter lateral stripes .... *Muscina* (Page 85)

5. Arista with branched bristles on its upper side; 4th. longitudinal vein with two angles and discal cell "cleaver" shaped (Fig. 43); pupa with two characteristic protuberances behind ..... *Glossina* Wiedemann (Page 87)

   Arista with simple bristles on one or both sides; fourth longitudinal vein not as above; discal cell normal in shape (Fig. 40); pupa without protuberances behind, resembling the pupa of Musca 6

6. Arista with bristles on upper side only 7

   Arista with bristles on both upper and lower side 9

7. Palpi very short much shorter than proboscis, entirely concealed when rostrum is retracted; haustellum long projecting well beyond head; 1st. and 3rd. longitudinal veins ciliated at base (Fig. 42).
Stomoxys Geoffry (Page 86)

Palpi as long or longer than proboscis, always visible when proboscis is at rest..8

8. First longitudinal vein nude, 3rd. longitudinal vein ciliated at base; palpi club shaped, as long as proboscis and somewhat curved upwards; proboscis short and blunt; first posterior cell narrowed; medium sized, robust flies..................................*Stygeromyia* Austen

First and 3rd. longitudinal veins nude at base; (Fig. 47) palpi straight and longer than proboscis; proboscis long and pointed; first posterior cell widely open; small flies....*Haematobia* Robineau-Desvoidy (Page 88)

9. First and 3rd. longitudinal veins ciliated at base; fourth longitudinal vein feebly curved; 1st. posterior cell widely open; palpi as long as proboscis, feebly club-shaped; sexual dimorphism marked.
Lyperosiops Townsend (Page 88)

First and 3rd. longitudinal veins nude at base..........................10

10. Palpi strongly spatulate; 4th. longitudinal vein feebly curved; 1st. posterior cell widely open; sternopleurals 2.
Bellolarynx Austen 1909

Palpi feebly spatulate; 4th. longitudinal vein strongly curved; 1st. posterior cell narrowly open; sternopleurals 2, the anterior small and at times absent.....................................*Haematobosca* Bezzi 1911

The Non-biting Muscidae

Genus Musca

Members of this Genus have their mouth parts adapted to suction only.

The Genus *Musca* has been divided into two groups, the non-blood sucking species and the blood sucking species (haematophagous). In the first group fall the domestic species which live on all kinds of animal and vegetable foods. This group includes *Musca domestica* Linnaeus.

The second group includes the wild species of Musca, which while they can not bite, they suck the blood which exudes from the bites of biting flies like *Tabanus* and *Stomoxys*, or serum which exudes from sores. This group includes *Musca autumnalis*. Members of this group breed in dung and probably not in human excrement and therefore would not be so important as the truly domestic *Musca* which may breed in human excrement.

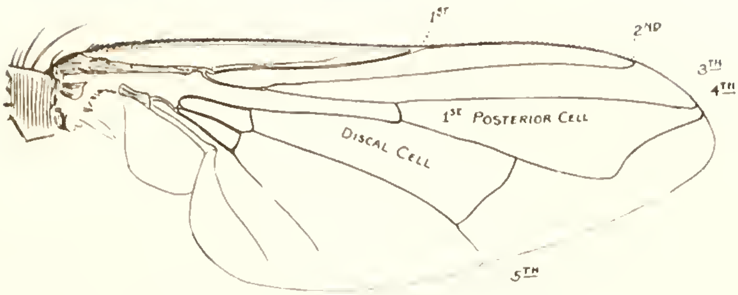

FIG. 40.—Wing of *Musca domestica.*

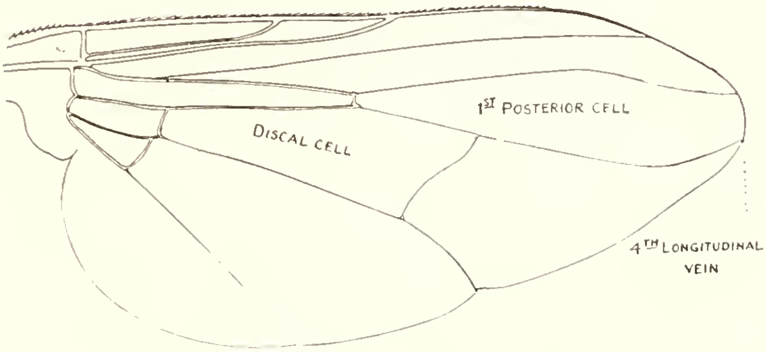

FIG. 41.—Wing of *Muscina stabulans.*

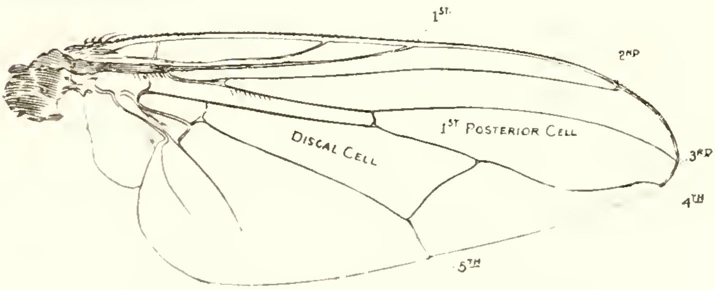

FIG. 42.—Wing of *Stomoxys calcitrans.*

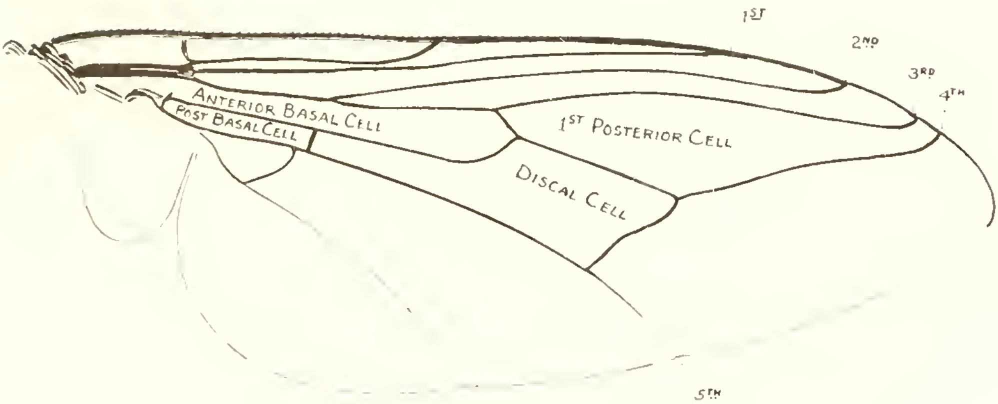

FIG. 43.—Wing of *Glossina morsitans.*

MUSCA DOMESTICA LINNAEUS

The thorax of the house fly or "typhoid" or "filth" fly as it is sometimes called, has four equally broad stripes on the dorsum, running longitudinally. Dorsally on the abdomen there is a median brown line and laterally a large yellow area. The arista is feathered dorsally and ventrally. The fourth longitudinal wing vein bends with a decided angle distally and the first posterior cell is almost closed. (Fig. 40.)

Life History.—The house fly lays its eggs, 120 or more in a batch, preferably in fresh stable refuse, but it may breed in human feces, garbage or other organic matter. It is not unlikely that a house fly which has actually bred in human excreta is a much greater menace to health than one which developes in manure and then merely rests on the surface of human excreta to feed or oviposite. The egg hatches within one or two days into a larva or maggot, a worm-like creature, which reaches its full development by succes-

FIG. 44.—Larva of *Musca domestica.*

sive moulting, in five to fourteen days. The larva (Fig. 44) is very active. When full grown it migrates to the bottom and towards the edge of the pile of organic matter, where it burrows into the ground if the soil is not too hard, to become a pupa inclosed in a hard, brown case. This is a typical coarctate pupa. In this stage which lasts from three to five days the insect is quiescent. The fully developed adult fly emerges through a circular split in the head end of the puparium or pupal case. Complete development from the time the egg is laid until the adult emerges requires from 10 to 20 days depending upon atmospheric temperature, and four days after complete development the females are capable of laying eggs.

Eggs are not laid in manure after fermentation has well begun, probably not after the first twenty four hours as the high temperature in the centre of the manure pile is inimical to the life of the larvae. Sunlight and drying are also unfavorable to their development. In order to pupate larvae will burrow into old manure if earthy material is not available or where the soil is too hard.

Extermination.—The logical way to exterminate flies is to eliminate their breeding places. Such procedure should go hand in hand with the screening of foods and of human habitations and privies.

Manure should invariably be collected from stables not less than every seven days, or before the larva has had an opportunity to pupate. If there be no connection with the ground development does not progress satisfactorily. Therefore a tight platform on which to pile the manure is advisable.

Where it is not possible to have frequent collections a light-tight manure bin should be constructed with a tight fitting cover, screened ventilation openings, and drainage into a sewer if available. The bin should have a concrete floor. In order to catch any flies which may develop within the bin it has been suggested that a fly trap made of fine wire mesh be constructed on the top, communicating by a small opening with the interior of the bin. As the fly is heliotropic it will naturally seek the light and pass from the dark interior to the trap outside. The trap may be detached from time to time and submerged in a pail or tub of water.

The use of chemicals, such as borax, petroleum, chloride of lime, etc., to prevent the breeding of flies in manure does not seem to produce the practical results that were expected. According to the United States Department of Agriculture, sodium borate or crude calcium borate are perhaps the best chemicals for the purpose, used in quantities of 0.62 pound borax or 0.75 pound crude calcium borate to every 8 bushels of manure, and applied immediately upon its removal from the stable. The chemical should be sprinkled particularly around the edge of the pile, and then wet with two or three gallons of water. This treatment must be repeated with each addition of fresh manure. The chemical in the amounts recommended does not destroy the fertilizing properties of stable manure.

The Richmond Health Authorities, taking advantage of certain factors in the life history of the fly, have developed what they have called a "maggot" trap. This depends for its efficiency upon the fact that larvae will crawl downward in the pile of manure in an effort to reach the ground to pupate and that the adult female will not lay her eggs in manure after fermentation has well begun. The maggot trap is essentially a manure bin without a cover and with a bottom of coarse mesh heavy wire. After the eggs develop larvae make their way downward and passing through the wire mesh fall into a concrete basin below which is kept full of water.

Here they drown. A film of oil should be kept on the surface of the water to prevent mosquito breeding. Two bins are usually in use, one in process of filling while the other, already full, is awaiting the migration of the larvae before the contents are removed.

Where possible it is sometimes best to burn stable refuse with the help of crude oil if necessary, thus effectually destroying eggs and larvae. It may be burned in windrows, or placed on a grating of heavy iron such as railroad iron, laid across a small gully, forming an improvised incinerator.

Manure may be spread in a thin layer on the ground so that sunlight may reach it and fly development will not take place. It may afterwards be plowed under as a fertilizer.

Remedial measures directed towards the eradication of flies after they have developed are rather hopeless. It then becomes necessary for individuals to protect themselves against the pest by an adequate screening of domiciles, privies, and food thus breaking the vicious circle of flies, feces, food and persons. Chemicals can be used in privies.

A swat-the-fly campaign after the insect has multiplied in great numbers is futile, although it may be possible that killing adult flies in the early part of the breeding season when there are but few and before they have had an opportunity to oviposite, may help to eliminate the pest. Various schemes have been devised to trap the adult fly with more or less success. The general principle involved is that a fly will enter a receptacle where food is present guided by the sense of smell, and will emerge because of its tendency to seek the light. This point may be taken advantage of in the construction of window screens. A space of one fourth of an inch should be left between the upper wooden strip of the frame and the screening material. A fly gaining access to the house through open doors etc., will crawl upward and out through this opening. In localities where mosquitoes are also a nuisance or a danger, screens should be made of No. 16 to 18 mesh. Where flies only are to be excluded a coarser mesh will serve the purpose. A fly-swatter is a convenient implement to have available. Fly traps are also useful.

Sticky fly paper is an excellent means of catching flies. A sticky substance which may be spread on paper, on spiral wire or on a wire coil, is made by dissolving 20 pounds of clear resin in 5 quarts of castor oil. Heat and stir until a clear solution is obtained. For

household purposes proportionately smaller amounts should be made up.

Garbage should be stored in water-tight, closely covered, metal receptacles, both rat proof and fly proof, and should be collected and incinerated at least twice a week.

Genus Muscina

Muscina stabulans, known as the non-biting stable fly, is a more or less common fly and may come into the house. It breeds in dung and decaying animal and vegetable matter but unlike the house fly its larvae are mainly carnivorous feeding on other larvae in the decomposing material.

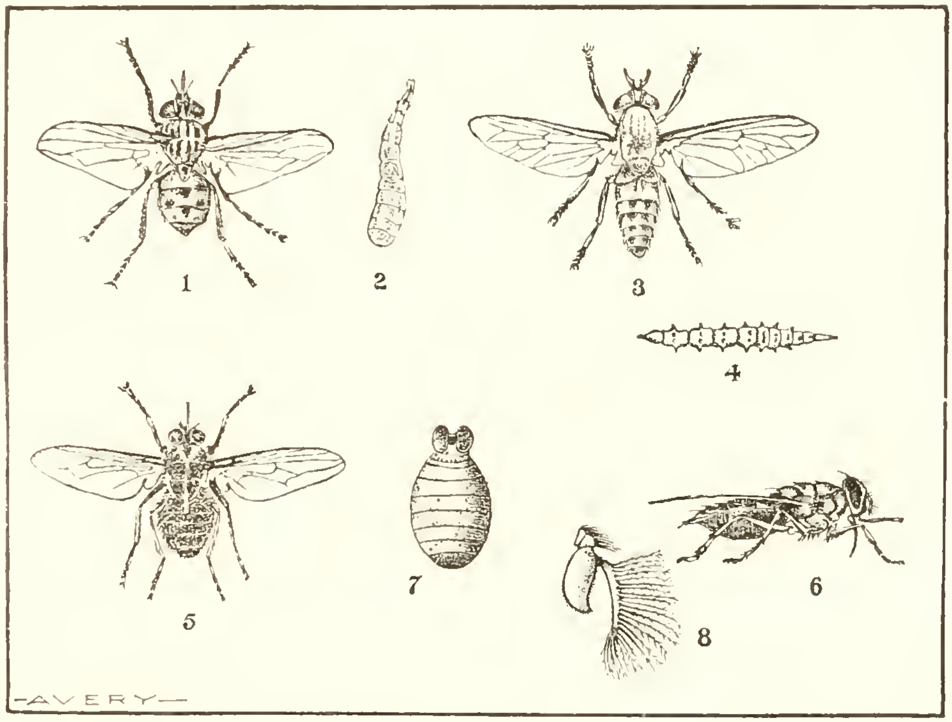

FIG. 45.—Insects in which the adult stage is important. (1) *Stomoxys calcitrans;* (2) *S. calcitrans*, larva; (3) *Tabanus bovinus;* (4) *Tabanus* larva; (5) *Glossina palpalis;* (6) *G. palpalis*, side view; (7) *G. palpalis*, pupa; (8) *Glossina*, palps and arista. (From "Stitt's Practical Bacteriology, Blood Work and Animal Parasitology," 7th Edition.)

Muscina assimilis is another member of the genus. Its legs, palpi and antennae are wholly black, whereas in the case of *Muscina stabulans* the legs are in part yellow, the palpi are yellow and the antennae are brown.

Genus Cryptolucilia

Cryptolucilia (Pseudopyrellia) caesarion Mg. is a common fly breeding in cow manure. Its thorax, abdomen, cheeks and vertex are bright shining green.

CHAPTER XI

THE BITING MUSCIDAE

Genus Philaematomyia Austin, 1909

These flies somewhat resemble *Musca domestica*. They are greyish in color with longitudinal dark stripes on dorsum of thorax. They may be recognized by their peculiar proboscis which is described elsewhere. Eggs are laid and hatched in cow dung. Pupation takes place in the ground. Time from oviposition to emergence of adult about 6 or 7 days. The adult feeds on cattle only occasionally attacking man. There are but three known species of which *P. insignis* is the commonest. These flies are not known in the United States.

Genus Stomoxys Geoffry

Flies of the genus Stomoxys resemble rather closely the common house fly but the long, tapering, chitinized proboscis adapted for biting will immediately differentiate them from *Musca domestica*. There are a number of species in the genus *Stomoxys* but the common one of the United States is *Stomoxys calcitrans* Linn. This fly is cosmopolitan in its distribution.

Stomoxys calcitrans Linn.

The arista is feathered dorsally. The palpi are slender and short, less than half the length of the proboscis. The fourth longitudinal

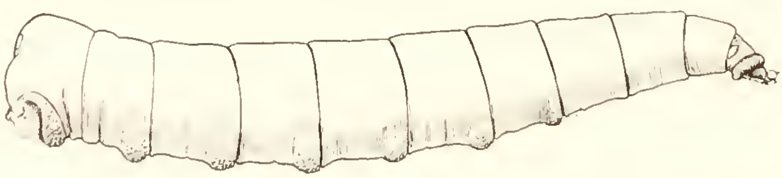

FIG. 46. Larva of *Stomoxys calcitrans*.

vein curves so as to merely narrow the first posterior cell which is therefore broadly open. (Fig. 42.) The first and third longitudinal veins are bristled at their proximal end. In the resting position the head is raised, the proboscis projecting forward. The legs

are black the abdomen is grey, the thorax is marked with clear black stripes and the abdomen with regular dark spots.

Eggs are laid on moist hay and straw, grass heaps, horse manure and decaying vegetable matter. Never in cow dung. They will breed in marine plants washed up on the beach. From egg to adult requires from 25 to 35 days. Egg stage 2 to 3 days, larval stage 14 to 21 days, pupal stage about 10 days.

The adults bite many different species of mammals including man and may come into the house before a rain. No disease in man nor animals has been traced to this fly.

To prevent the breeding of this fly care should be taken to properly dispose of rotting hay and straw and manure.

Genus Glossina Wiedemann

(Tsetse Flies)

These flies are confined to tropical Africa and Arabia and are of great interest because they carry sleeping sickness (Trypanosomiasis). One species *Glossina palpalis* Robineau-Desvoidy carries *Trypanosoma castellanii* and one, *Glossina morsitans* Westwood carries *Trypanosoma rhodesiense*. There are about 17 known species in the Genus.

The Glossinae have narrow bodies, they are dull colored greyish or yellowish brown, with the wings closed flat one over the other and projecting when at rest considerably beyond the abdomen. The palpi are as long as the proboscis and enclose it. The proboscis projects forward and its base is bulbous. The arista is feathered with branched bristles dorsally only. The fourth longitudinal vein has two sharp bends. The discal cell is cleaver shaped, a characteristic point. The first posterior cell is narrowly open.

Glossina palpalis is a dark medium sized fly with the thorax bluish gray to olive gray and marked with brown stripes. The abdomen is dark brown marked with pale and dark triangular areas. The hind tarsi are entirely dark and the third joint of the antenna is dusky brown to black. It is the insect host for *Trypanosoma gambiense*, its distribution corresponding to the area in which the Northern form of sleeping sickness is endemic.

Glossina morsitans is a light colored medium sized fly with a light grey streaked thorax. The abdomen is buff colored with spots and bands. The last two joints of the fore and midtarsi have sharply defined dark brown or black tips.

Glossinae live in jungles or bushes along the banks of lakes or streams, although *G. morsitans* is not so restricted in its range as *G. palpalis*. They suck the blood of many of the large wild animals of the locality. They bite principally during the middle of the day.

The female deposits a single fully developed larva which has been nourished within its uterus, growth taking about eight or ten days. The larva immediately seeks a place under ground, usually near the roots of shrubs and trees, and in a few hours becomes a pupa which develop into the fully formed adult in about six weeks. This period depends more or less upon atmospheric temperature. The larva bears on its last segment two prominent rounded granular black projections between which is a pit bearing two stigmal plates.

Genus Haematobia Robineau-Desvoidy

(Horn Flies)

(Synonym *Lyperosia*)

These flies are very troublesome to cattle. They are about one-half as large as the common house fly. They resemble *Stomoxys* but are smaller and have straight feebly clubbed palpi longer than the

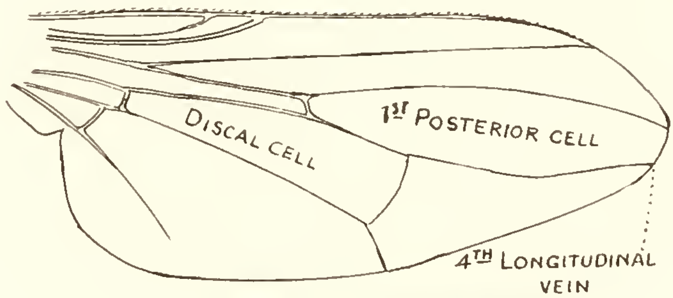

FIG. 47.—Wing of *Haematobia irritans*.

proboscis. The arista is haired dorsally only. The fourth longitudinal vein is feebly curved and the first posterior cell is widely open. The common horn fly of the United States is *Haematobia irritans*.

The female lays her eggs in fresh cow manure. Darting from the animal as soon as the dung is passed, she deposits her eggs hurriedly and immediately returns to the host. The length of time to develop from egg to adult is about two weeks. Pupation takes place in the soil.

Genus Lyperosiops Townsend

This Genus is one proposed by Townsend to take the place of *Haematobia* as used in most books. *Haematobia* is the exact synonym of *Lyperosia* as shown by the type *irritans*. *Haematobia* takes precedence over *Lyperosia*.

The type of *Lyperosiops* is *stimulans*. It is a European and Oriental fly not found in the United States. The species of *Lyperosiops* are distinguished by the arista having 5 to 8 bristles above and 3 to 4 below. The fourth vein is feebly curved and the first posterior cell is widely open. There is marked sexual dimorphism.

CHAPTER XII

OTHER NON-BITING MUSCOIDEAN FLIES

FAMILY SARCOPHAGIDAE

Key to the Genera (J. M. Aldrich, 1916)*

1. Abdomen wholly shining black; arista long-plumose (tropics). *Phrissopodia* Macq.
   Abdomen with three rows of shining black spots on the second, third and fourth segments; these are sometimes confluent, but at least the intervening angles are densely pollinose; arista pubescent (widespread north) (Page 93)................................*Wohlfahrtia* B. and B.
   Abdomen pollinose, at most the hinder part of the segments shining black in certain lights, tessellated in others................................2
2. Veins 1, 3, and 5 hairy; first posterior cell closed and short petiolate (tropical)................................*Johnsonia* Coq.
   Vein 5 always bare................................3
3. Male with one orbital bristle, proclinate (the uppermost frontal sometimes simulating another, but reclinate)................................4
   Male without orbital................................6
4. Front protuberant; vibrissae approximated and high above oral margin (Louisiana)................................*Camptops* Aldrich
   Front not protuberant, vibrissae as usual................................5
5. Metacephalon greatly developed, hence the lower edge of head remarkably long, produced backward (tropical)...........*Sarothromyia* B. and B.
   Metacephalon not greatly developed (tropical).....*Sarcophagula* V. d. W.
6. Arista short-plumose................................7
   Arista long-plumose................................10
7. Parafacial with a single macrochaeta below, proclinate (Louisiana, Texas. *Camptopyga* Aldrich
   Parafacial with a row of hairs................................8
8. No costal spine (widespread north)....................*Agria* Desvoidy.
   Costal spine strongly developed................................9
9. Back of head with only black hair; anterior acrostichals very large (northeastern)................................*Harbeckia* Aldrich
   Back of head with some pale hair; no anterior acrostichals (widespread). *Hypopelta* Aldrich
10. Two large posterior dorsocentrals, two equally large anterior ones (tropical). *Notochaeta* Aldrich
    Generally three or four posterior dorsocentrals, if only two the anterior ones are much reduced................................11

* Sarcophaga and Allies. Published by the Thomas Say Foundation.

11. Vibrissae approximated and high above the oral margin (the distance equaling the length of the second antennal joint) (widespread).
Emblemasoma Aldrich

Vibrissae normal, or if somewhat approximated they are not strikingly removed from the oral margin.......................................12

12. Parafacials quite bare; first vein hairy (Louisiana). . *Sthenopyga* Aldrich

Paraficials with hairs, sometimes delicate..............................13

13. Ocellars absent; frontal rows not noticeably divergent below, reaching base of antennae (tropical)........................*Harpagopyga* Aldrich

Ocellars present; if absent, the frontal rows are abruptly divergent below and reach about to the middle of second antennal joint................14

14. Fifth sternite of male undivided; epaulet yellow; back of head with only black hair (northeastern)........................*Thelodiscus* Aldrich

Fifth sternite of male deeply divided (widespread) (Page 93).
Sarcophaga Meig.

Description. The Sarcophagidae have large bodies. The arista is feathered dorsally and ventrally in the basal half but is naked and hair-like in the distal half. The legs are stout. The abdomen is grey with whitish or silvery, tesselated or changeable spots. The fourth vein ends considerably before the apex of the wing with an almost angular bend. The parafacials are hairy. There are no discal bristles on the abdomen and not more than a single pair of discal scutellar bristles. The palpi are well developed. The eyes are never hairy. The proboscis is of the sucking non-biting type similar to that of the house fly. The abdomen has four main segments—four tergites and four sternites. Because of the fact that the first and second sternite are united, the last visible sternite is really the fifth. This sternite is forked behind and may have brushes of short spines, blunt processes etc. which are of specific importance.

As in many other Diptera, a study of the accessory organs of generation is of value in determining the species. (Fig. 48.) Terminating the abdomen just back of the fourth segment in the male are two small segments which together are known as the *hypopygium* or genital segments. They serve to protect and give attachment to the accessory organs, which consist of two *forceps*, two *accessory plates* and a pair each of *anterior* and *posterior claspers*. These organs can not be studied unless the end of the abdomen is drawn out as far as possible without tearing the tissues. Dried specimens should be kept in the relaxing chamber at least 24 hours before this is attempted. The penis lies in the middle line in front of the forceps and between the claspers. The anus is located at the end of the second segment of the hypopygium.

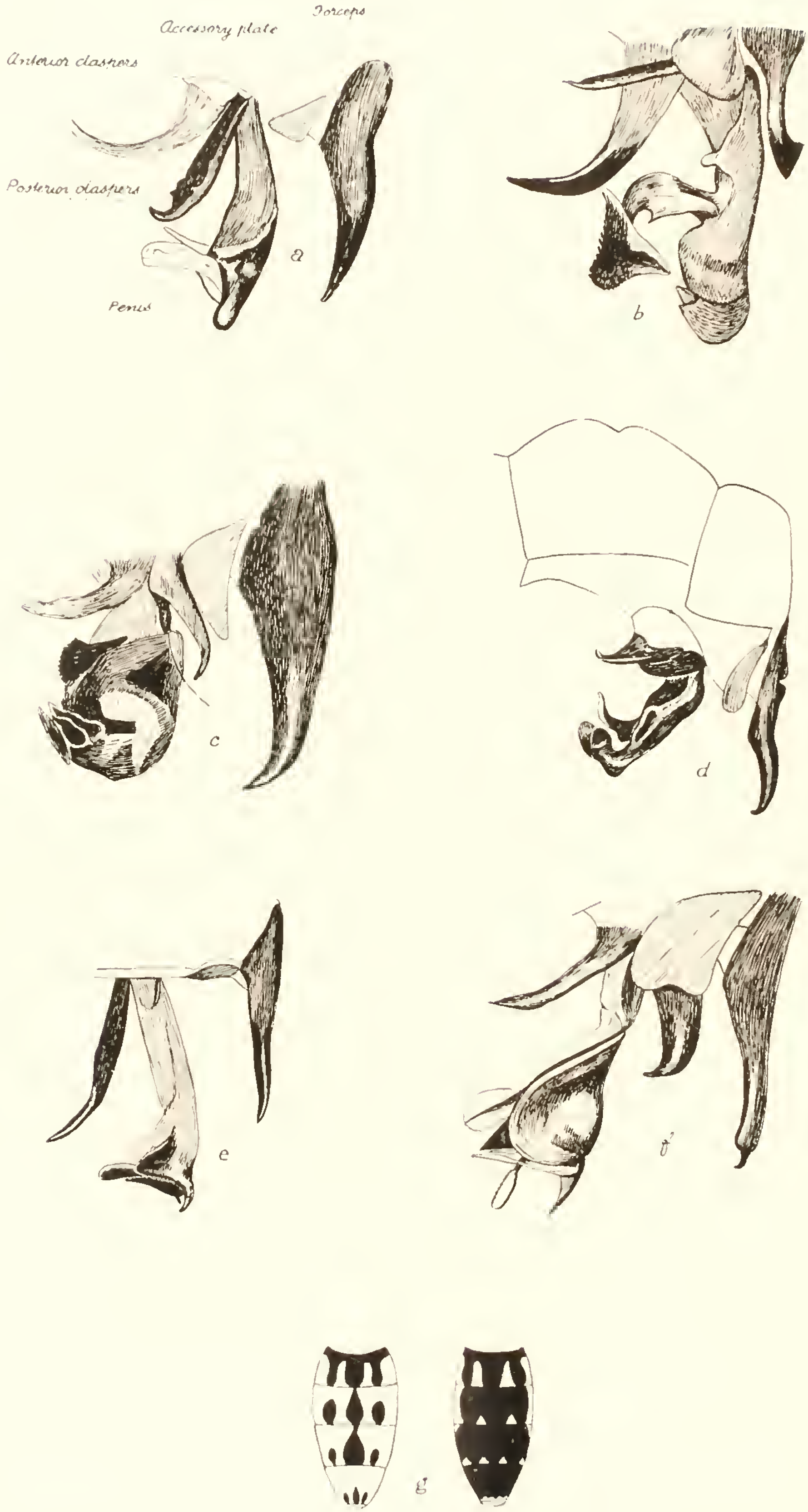

FIG. 48.—Male genitalia of some of the *Sarcophaga*. (a) *S. communis;* (b) *S. assidua;* (c) *S. bullata;* (d) *S. haemorrhoidalis;* (e) *S. quadrisetosa;* (f) *S. sarracenioides;* (g) Dorsum of abdomen of *Wohlfahrtia meigenii* (left) and *Wohlfahrtia vigil* (right). (From Aldrich, "Sarcophaga and Allies in North America." The Thomas Say Foundation.)

Larva.—The Sarcophagidae are larviparous. The larva is tapering. (Fig. 36.) There are two great hooks at the small, the head, end. The stigmal plates have no button and lie at the bottom of a pit. (Fig. 49.) The slits of the stigmal plates are not sinuous, they are slender and are subparallel to each other. The slits in one plate are subparallel to those in the opposite plate. The fusiform areas completely encircle the segments. There are distinct tubercles above the anal area and around the stigmal field.

Habits.—In habits the larvae range from scavengers to parasites of warm blooded animals. They have been reared from human and animal excrement, from carrion and from dead insects. Some are also parasites of living insects.

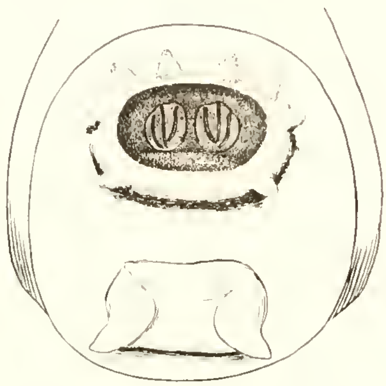

FIG. 49.—Last abdominal segment of a Sarcophagid fly.

Genus Sarcophaga

Most of the members of the Family belong to the Genus *Sarcophaga*. A common species in North America is *Sarcophaga communis* Parker which breeds in carrion and will breed in human excrement. It is abundant in the North but in the South it is replaced by a variety, *Sarcophaga communis* var. *ochracea* Aldrich. Another common species in the United States is *Sarcophaga haemorrhoidalis* Fallen. This is cosmopolitan in its distribution. It is also a scavanger and has been bred from human excrement and has been passed in the stools. It is quite likely that this species is not infrequently a cause of intestinal myiasis and the larvae seem to be capable of developing within the intestinal canal of man. The following species have also been bred in human excreta: *Sarcophaga quadrisetosa* Coquillett, *Sarcophaga assidua* Walker, *Sarcophaga sarracenioides* Aldrich, a variety of *S. tuberosa* Pandelle, *S. pachyproca* Parker and *S. bullata* Parker.

Sarcophaga carnaria, a European species may be the cause of nasal, intestinal or cutaneous myiasis. It normally breeds in tainted flesh.

Genus Wohlfahrtia

The Genus *Wohlfahrtia* is also of interest because it may be a cause of nasal and cutaneous myiasis. A European form is, in

habits, similar to the North American Screw-Worm fly, *Cochliomyia macellaria* Fabricius. Two species are found in the United States, a Western form, *Wohlfahrtia meigenii* Schiner and an Eastern form, *Wohlfahrtia vigil* Walker. Larvae of the latter have been taken from beneath the skin of infants. The western form may have the same habit.

In *W. meigenii* the abdomen is mostly pollinose, its black spots small. In *W. vigil* the black spots are large and confluent, the pollinose part not being very conspicuous.

Key to the More Common and Widespread Species of the Genus Sarcophaga in the United States. (Condensed from Aldrich's Key)

I. Three distinct postsutural dorso-central bristles.

Group A. Hind tibiae with villosity (with erect hairs); both segments of hypopygium black.

1. Middle tibiae with a patch of yellow hair covering the apical third of the front side.................................*sinuata* Meigen

Group B. Hind tibiae with erect hairs; at least the second segment of the hypopygium red.

1. First vein bare; front without orbital bristle in male; legs black; hind femora on outer side with a median row or part of a row of longer bristles than the upper and lower rows; sternites 1–4 not successively narrowed; anterior acrostichals present.........................2
   Same but anterior acrostichals absent...........................3
2. With an almost complete median row of bristles on hind femur. *cimbicis* Townsend
   With only the distal end of the row present; the accessory plate slender, finger-like.................................*latisterna* Parker
3. With a complete median row of bristles on hind femur...*bisetosa* Parker

Group C. Hind tibiae not with erect hairs, at the utmost with a few appressed hairs; hypopygium wholly black.

1. First vein hairy...4
   First vein bare..2
2. Male without orbitals; frontals extending below base of antennae; anterior acrostichals large; arista short-plumose; hypopygium large.................................*Agria affinis* Fallen
   Same but arista as usual; hypopygium small.....................3
3. Second segment of hypopygium opaque; palpi yellow; forceps slender largely yellow and having a protuberance on the attached part on which is a striking tuft of long straight black hair, which is invisible in repose...*hunteri* Hough
   Same but forceps not with such tuft; Distal segment of penis thickened from its base.................................*opifera* Coquillett
4. Second abdominal segment with erect median marginal bristles; distal segment of penis full and globular, flat behind..*melampyga* Aldrich

Group D. Hind tibiae not with erect hairs; at least the second segment of hypopygium red or reddish yellow.

1. First vein hairy 14
   First vein bare 2
2. Palpi yellow 3
   Palpi black 4
3. Legs black; outer vertical bristles absent in male; first segment of hypopygium with row of bristles at apex, often indistinct; small species; forceps with a pair of processes in the basal attached part which bear a striking tuft of long straight black hair, concealed in repose . . . . *hunteri* Hough
   Same but forceps not with such processes or tufts . . *opifera* Coquillett
4. Arista long and thin, short-plumose; hypopygium large, second segment red with long upcurved bristles . . *Hypopelta scrofa* Aldrich
   Arista normal; both segments of hypopygium reddish yellow 5
5. Frontal rows of bristles not strongly divergent below; epaulets yellow. *peniculata* Parker
   Frontal rows suddenly diverging in the last two or three bristles; epaulets black 6
6. Anterior acrostichal bristles well developed; parafacials gray; penis with a pair of erect recurved hooks on the back near apex 7
   Same but penis not with hooks on back 8
7. Accessory plate at least twice as long as wide; not excised; distal segment of penis slender narrowed at tip . . . . *alcedo* Aldrich
8. Distal segment of penis in the form of a long tube, incurved at the end and forming a loop that can be seen through in profile beyond the lateral processes . . . . *reversa* Aldrich
   Distal portion not forming a loop that can be seen through 9
9. Distal segment of the penis on its apical half with lateral thin expanded margins which are whitish or transparent somewhat like a ruffle . . . 10
   Penis not with ruffle-like expansion 13
10. Distal segment (beyond the hinge) evidently divided into two subsegments 11
    Distal segment not so divided 12
11. The division of the distal segment is near the tip, which is divided into two delicate processes attached to the fringe. *marginata* Aldrich

    The division is just beyond the middle, the apex broadly and deeply cleft into two strong but flat claws which are not connected with the fringe . . . . *falciformis* Aldrich
12. The chitinous distal segment is notched into two sharp points at apex; a pair of erect median marginal bristles on second abdominal segment . . . . *setigera* Aldrich
    The distal segment is swollen and whitish near end, not perceptibly notched; rarely with median marginals on second abdominal segment . . . . *coloradensis* Aldrich

13. Second abdominal segment without median marginals; front at least .16 of head width; the stout divergent prongs at the tip of the penis cover and conceal the minute incurved copulatory tube or at most have a V shaped opening. . . . . *aculeata* Aldrich

14. Tibiae black; first segment of hypopygium very large, flat behind, giving the abdomen a truncated appearance; acrostichals well developed. . . . . *pachyprocta* Parker

Tibiae black; first segment of hypopygium retracted almost invisible; anterior acrostichals hardly differentiated from hairs. *helicis* Townsend

II. Four post-sutural dorsocentral bristles or else the anterior ones of the post-sutural series indistinct, hardly differentiated from hairs.

Group E. Hind tibiae with erect hairs; hypopygium entirely black.

1. Front about as wide as one eye; middle tibiae with long dense hairs on distal half of inner side; very robust species. (Atlantic seaboard from Massachusetts to Texas.). . . . . *johnsoni* Aldrich

Group F. Hind tibiae with erect hairs; at least second segment of hypopygium red.

1. First vein bare; legs black; first segment of hypopygium black at least on apical half. 2

Same but first segment yellow at least on apical half. 5

2. Prescutellar bristles absent; forceps nearly straight in profile with a notch behind near base. . . . . *haemorrhoidalis* Fallen

Prescutellar bristles present. 3

3. Middle tibiae with out erect hairs, with a single row of black hairs behind the eye. . . . . *securifera* Villeneuve

With more than one row of black hairs. 4

4. Forceps in profile with an emargination behind followed by a hump. *falculata* Pandelle

Forceps not with a hump; penis with four slender processes at tip. *tuberosa* var. *exuberans* Pandelle

5. Middle tibiae without erect hairs; at most with appressed hairs as long as the tibia is wide; parafacials gray or with but little yellowish tinge and with distinct hairs; the row of bristles on the fourth abdominal segment entirely marginal; anterior acrostichals not differentiated at most faintly discernible at front edge of thorax; third abdominal segment with median marginal bristles; forceps with nearly parallel front and back edges and an apical tooth formed by an excision of the front edge. . . . . *sarracenioides* Aldrich

Same but forceps tapering to a sharp point; distal segment of penis short and very broad and blunt, a curved horn-like process at each outer apical angle. . . . . *bullata* Parker

Group G. Hind tibiae without erect hairs; both segments of hypopygium black.

1. First vein hairy. . . . . *salva* Aldrich

Group H. Hind tibiae of male without erect hairs; at least the second segment of hypopygium red.

1. First vein hairy 7
   First vein bare 2
2. Epaulet largely yellow; frontals not or but little divergent anteriorly; scutellum without a pair of small apical bristles in male 3
   Epaulets black 4
3. Palpi and legs black; front about half as wide as one eye; evidently narrowed below the ocelli; parafrontals and parafacials gray, pollinose; first segment of hypopygium black (very common north) . . . . *communis* Parker
   Same but parafrontals and parafacials yellow, pollinose; first segment of hypopygium red (very common south).
   communis var. *ochracea* Aldrich
4. Vibrissae not farther above the oral margin than half the length of second antennal joint, generally not unusually approximated; palpi black; one or two pairs of strong erect anterior acrosthicals, several times as large as adjacent hairs; anterior dorsocentrals also large and erect. Forceps with barb like projection behind.
   kellyi Aldrich
   Same but acrostichals either undifferentiated or but little larger than adjacent hairs 5
5. Scutellum with a pair of small apical bristles between the large marginals 6
   Scutellum without small apicals; front much narrower than the width of one eye; fifth sternite with the sides not diverging; forceps in back view decidedly diverging at the tip, very small; hind tibiae not hairy; anterior claspers long not very stout . . . . *assidua* Walker
6. Back of head with two rows of black hairs behind eye; large stout species without median marginals on third abdominal segment.
   plinthopyga Wiedeman
   Back of head with three rows of black hairs behind eye; frontal rows suddenly divergent at lower end; outer vertical present; forceps with dense erect short hair almost at tip . . . . *utilis* Aldrich
7. Lateral vertical bristles generally present; forceps divergent.
   latisetosa Parker
   Lateral vertical bristles absent; stalk of penis very long, on the front side just before tip with a flat yellow transverse plate projecting forward . . . . *quadrisetosa* Coquillett

FAMILY CALLIPHORIDAE

Description.—Members of the Family Calliphoridae have the mouth parts well developed and adapted to suction only, as typified in the house fly. Hypopleural bristles are present; notopleural bristles 2; sternopleurals 2 : 1 or 1 : 1, never 1 : 1 : 1; post humerals usually laterad of presutural, sometimes in line with presutural, rarely absent, never mesad of presutural; hind coxae bare behind above

base of hind femur; wing venation of the Muscid type. The abdomen or the abdomen and thorax is usually of a bright metallic color but sometimes yellowish or blackish. The thorax is usually without stripes or bands.

Habits.—These flies are commonly known as blue or green bottle flies. They are scavangers breeding in fresh or decaying meat or human or animal excrement and may be the cause of myiasis in its several forms.

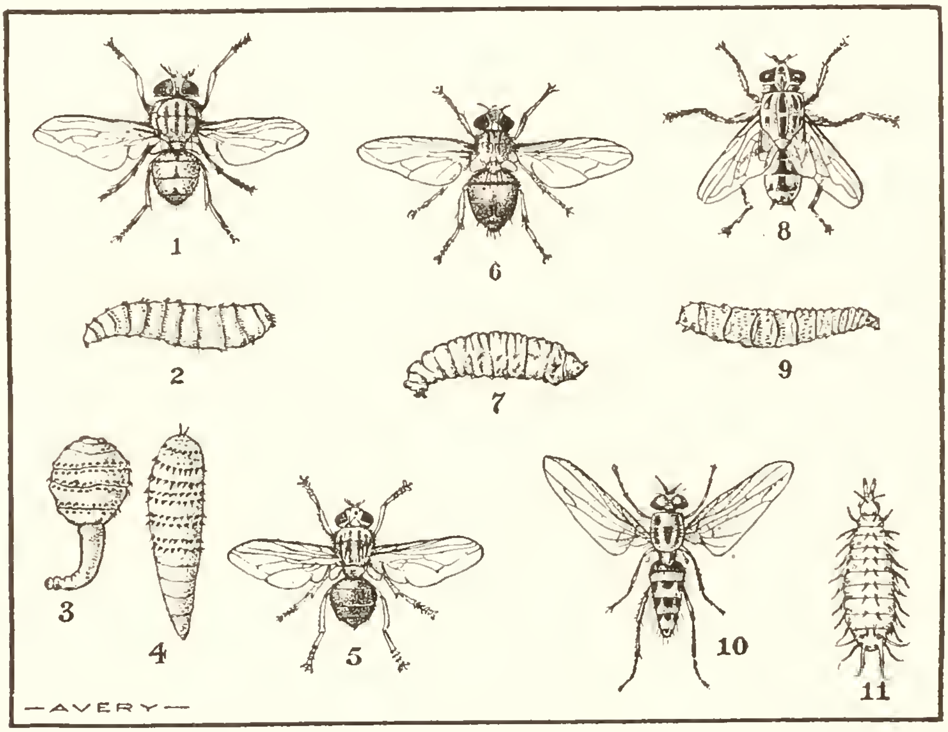

FIG. 50.—Insects in which the larval stage is important. (1) *Cochliomyia macellaria;* (2) *C. macellaria*, larva; (3) *Dermatobia hominis* larva, early stage; (4) *D. hominis* larva, later stage; (5) *Dermatobia hominis;* (6) *Auchmeromyia luteola;* (7) *A. luteola*, larva; (8) *Sarcophaga magnifica;* (9) *S. magnifica* larva; (10) *Anthomyia pluvialis;* (11) *A. pluvialis* larva. (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology," 7th Edition.)

Larva. The larva is tapering and has two great hooks at the small or head end. The slits in the stigmal plates are not sinuous, they are slender and directed rather transverse to the body. The plates are provided with a button and are not placed at the bottom of a pit as in Sarcophagidae. There are tubercles about the anal area and processes around the stigmal field. The roughened area may encircle the segments.

Among the Calliphoridae which are not some metallic shade of blue or green are the Genera *Pollenia* and *Melanodexia*, greyish and

nonmetallic in coloration. In these genera the sternopleurals are 1:1; the prosternum and propleura are bare and the parafacials are hairy down to the lowermost margin of the eye. In all other Calliphoridae, American at least, the prosternum and the propleura are hairy.

Other nonmetallic genera which may be mentioned, are the yellowish or brownish yellow—testaceous—Calliphoridae, *Mesembrinella* (blow flies of South American) and *Auchmeromyia* and *Bengalia* both African genera of medical interest.

Key to the Genera of Calliphoridae (R. C. Shannon, 1923)*

1. Prosternum and propleura bare; sterno-pleurals 1:1; parafacials hairy down to lowermost margin of eye. (Subfamily Polleninae.)
   - A. Thorax with abundant deciduous pile; two sublateral bristles; post-humerals present (Page 106) .... *Pollenia*
   - AA. Thorax without deciduous pile; one sublateral bristle; post-humerals absent .... *Melanodexia*
2. Prosternum and propleura pilose; sternopleurals 2:1.
   - A. Upper side of stem of first vein ciliated; subcosta sclerite with small black bristles. (Subfamily Phorminae.)
     - B. Face yellow with yellow pile; anterior portion of lower squama pilose; one post-humeral bristle.
       - C. Palpi normal with well scattered bristles; three or four propleural bristles; post-thoracic spiracle light-colored with a row of black hairs along its lower margin (*Chrysomyia fulvipes* Macq. (*wheeleri* Hgh., syn. by Aldrich)) .... *Compsomyiops* Townsend
       - CC. Palpi about one-third normal size with bristles placed on outer third; post-thoracic spiracle darkened. (*Chrysomyia macellaria* Fab.) see Footnote† (Page 105) .... *Cochliomyia* Townsend
     - BB. Face black with black hairs; lower squamae bare; usually two post-humeral bristles.
       - C. Disc of upper squama bare; anterior acrostichals well distinguishable from surrounding hairs.
         - D. Four intra-alars; six or more marginal scutellars; prothoracic spiracle dark orange to black (*metallica* Tns.) (Page 106). *Protocalliphora* Hough
         - DD. Two intra-alars; four marginal scutellars; prothoracic spiracle distinctly light orange colored (*regina* Mg) (Page 105). *Phormia* Robineau-Desvoidy
       - CC. Disc of upper squama thinly pilose; anterior acrosticals not distinct from surrounding hairs; prothoracic spiracle black.

* Genera of nearctic Calliphoridae, blow flies, with Revision of the Calliphorini. Insecutor Inscitiae Menstruus, Vol. XI, 1923, Nos. 7-9, pp. 100-110.

† Where there is only one North American species it is noted in parenthesis.

D. Aristal rays closely applied to arista; face much produced below, making the head as high as broad; prothoracic spiracle noticeably larger than third antennal joint. (*aristatus* Ald. & Snn. (*Phormia coerulea* Mall., preoc.)....*Boreëlus* Ald. & Snn.

DD. Aristal rays well separated; face moderately produced below, noticeably broader than high; prothoracic spiracle about size of third antennal joint. (*terraenovae* Desv.) (Page 105). *Protophormia* Townsend

AA. Upper side of stem vein bare; subcosta sclerite faintly pubescent; one post-humeral bristle. (Subfamily Calliphorinae.)

B. Upper surface of lower squama bare; a small chitinized hairy patch present on posterior end of the membrane between lower squama and lower margin of the post-alar declivity (*caesar*, et al) (Page 104). *Lucilia* Desvoidy

BB. Upper surface of lower squama distinctly pilose; above mentioned patch absent.

C. One sublateral; two bristles near middle on exterior surface of front tibia (Page 000)....................*Cynomyia* Desvoidy

CC. Two or three sublaterals; one, rarely two, bristles midway on exterior surface of fore tibia.

D. Two sublaterals (Acrophaga BB.)......*Steringomyia* Pokoray

DD. Three sublaterals.

E. Last section of fourth vein straight or but very slightly curved; antennae black, small, third joint only as long as dorsal bristle of second joint..........................*Onesia* Desvoidy

EE. Last section of fourth vein with a decided bend; antennae normal in size, third joint much longer than bristle of second joint..............................*Calliphora* Desvoidy

Synopsis of Calliphorini (R. C. Shannon)

Males

A. Outer forceps very elongate; inner ones rudimentary; one sublateral. *Cynomyia*

B. Entire front of head, bright golden yellow with silvery pruinosity. *mortuorum* Linne

BB. Facial plate dark, genae reddish brown............*cadaverina* Desvoidy

AA. Outer forceps not very elongate; inner ones well developed, being nearly as long to longer than outer; two or three sublaterals.

B. Lobes of fifth sternite very prominent, obtusely rounded apically; two sublaterals..*Steringomyia*

C. Narrowest width of front much broader than width of parafacials; bristles on parafrontals continue all the way to the inner verticals; lower half of parafacials distinctly reddish brown; inner forceps longer than outer; squamae white....... ....*alpina* Zett

CC. Narrowest width of front not broader than parafacials; bristles on parafrontals and below level of anterior ocellus; parafacials black; squamae darkened.

D. Parafacial broader than narrowest width of front; inner forceps as long as outer, much broadened basally, flat, in outline pear-shaped. . . . . *alaskensis* Shannon

DD. Parafacials of same width as narrowest part of front; forceps very slender, about two and one half times as long as combined width; inner ones much shorter than outer. . . . . *aldrichia* Shannon

BB. Lobes of fifth sternite inconspicuous, appressed, except *elongata* which has them truncate; three sublaterals.

C. Last section of fourth vein straight or only slightly bowed inward; third antennal joint small, about as long as dorsal bristle of second antennal joint; forceps small. . . . . *Onesia*

D. Third antennal joint distinctly longer than width of parafacial; wings and squamae smoky; forceps very small, outer ones rounded apically, their basal halves overlapped by hypopygium. *aculeata* Pandell

DD. Third antennal joint slightly shorter than width of parafacial, wings and squamae very slightly tinged; forceps not unusually small, outer ones pointed, thick and irregular in outline; inner ones more deeply inset than outer. . . . . *agilis* Meigen

CC. Last section of fourth vein with a decided bend; third joint normal sized, much longer than bristle of second joint. . . . *Calliphora*

D. Front of head bright orange with silvery pruinescence; pair fronto-orbitals; only five pairs of frontals; forceps moderate, of equal development, slender and curved apically; squamae white. *elongata* Hough

DD. Front of head partly black; no fronto-orbitals; squamae darkened.

E. Narrowest width of front over twice as broad as parafacial; a well differentiated pair of secondary ocellars placed immediately behind post-ocelli; forceps very small; outer ones nearly bare; inner ones very hairy on post-aspect. . . . *latifrons* Hough

EE. Narrowest width of front much less than twice width of parafacial; secondary pair ocellars not well differentiated from surrounding hairs.

F. Three intra-alars; basicosta black; outer forceps well provided with long, loose hairs.

G. Narrowest width of front broader than width of parafacial; bucca mostly reddish; outer forceps regular in outline, obtusely pointed. . . . . *coloradensis* Hough

GG. Narrowest width of front less than half the width of parafacial; bucca black; outer forceps suddenly curved at apex, sharply pointed. *viridescens* Desvoidy

FF. Two intra-alars.

G. Basicosta yellowish; outer forceps with long, loose hairs, broad, obtusely rounded at apex; bucca red. *erythrocephala* Meigen

GG. Basicosta black; bucca black.

H. Parafacials black; outer forceps straight, comparatively broad, gradually tapering to obtuse point, clothed with short, stiff hairs. *morticia* Shannon

HH. Lower half of parafacials red; outer forceps gently curved, very slender, sharply pointed, nearly bare. *vomitoria* Linne

I. Beard red. . . . . *vomitoria vomitoria*

II. Beard black. . . . . *vomitoria nigribarba* Shannon

Table of Females

A. One sublateral; two bristles about midway on exterior side of fore tibia. *Cynomyia*

B. Entire front of head bright orange yellow. . . . . *mortuorum* Linne

BB. Front and facial plate black. . . . . *cadaverina* Desvoidy

AA. Two or three sublaterals; one bristle midway on outer side of fore tibia.

B. Two sublaterals; slender species. . . . . *Steringomyia*

C. Plumosity of arista two-thirds normal length; squamae white. *popoffana* Townsend

CC. Plumosity normal; squamae darkened.

D. Lower fronto-orbital on level with fifth frontal; disc of fourth segment with strong bristles and sparse, short hairs. *aldrichia* Shannon

DD. Lower fronto-orbital on level with sixth frontal; disc of fourth segment conspicuously haired, bristles weak. Probably female of. . . . . *alaskensis* Shannon

BB. Three sublaterals, usually robust species.

C. Last section of fourth vein very slightly bowed inward; antennae black, small, third joint only as long as bristle of second joint; frontal vitta twice as long as broad; rather small species. . . . *Onesia agilis* Meigen

CC. Last section of fourth vein with decided bend; antennae of normal size, partly red; frontal vitta less than twice as long as wide. *Calliphora*

D. Post-margin of second tergite without long bristles except at sides; squamae white; basicosta yellow. . . . . *elongata* Hough

DD. Post-margin of second tergite with appressed long bristles extending across; squamae darkened.

E. A strongly differentiated pair of secondary ocellars placed immediately behind post-ocelli; bristles on facial ridges well developed, lower ones longer than width of parafacial. *latifrons* Hough

EE. Secondary ocellars hardly differentiated from surrounding hairs; facial ridge bristles much smaller.

F. Three intra-alars; basicosta black.

G. Bucca red. . . . . *coloradensis* Hough

GG. Bucca black. . . . . *viridescens* Desvoidy

FF. Two intra-alars.

G. Basicosta yellowish; bucca reddish. . . . *erythrocephala* Meigen

GG. Basicosta black; bucca black.

H. Head as high as broad; parafacials normally black. *morticia* Shannon

HH. Head broader than high; lower half of parafacials reddish. *vomitoria* Linne

I. Beard reddish. . . . . *vomitoria vomitoria*

II. Beard black. . . . . *vomitoria nigribarba* Shannon

Kep to the Tribe Luciliini (R. C. Shannon, 1924)*

Table of Males

A. Arista brevi-plumose, the dorsal bristles of first antennal joint being of equal length; two sublaterals (third sublateral absent), three intra-alars (Genus *Francilia* Shannon). . . . . *alaskensis* Shannon

AA. Arista of normal plumosity; three sublaterals; two intra-alars (first one absent) (Genus *Lucilia*).

B. Basicosta black.

C. Palpi yellow; two post acrostichals; subcostal sclerite with black setae *caesar* Linne

CC. Palpi dark brown to blackish; three post acrostichals; subcostal sclerite without setae. . . . . *sylvarum* Meigen

BB. Basicosta yellow.

C. Two post acrostichals.

D. Beard black; parafrontals very narrow, contiguous; second tergite with post margin concolorous with rest of segment. *australis* Towns. and *unicolor* Townsend.

DD. Beard mostly yellow; parafrontals separated by width of a parafrontal; second tergite with post margin bluish black. *pilatei* Hough

CC. Three post acrostichals.

D. Hypopygium conspicuous; lobes of fifth sternite prominent, ligulate, with dense long hairs. . . . . *pallescens* Shannon

DD. Hypopygium nearly concealed, lobes of fifth sternite inconspicuous, appressed, with shorter, stiffer hairs. . . . . . *sericata* Meigen

Table of Females

A. Basicosta black.

B. Three post acrostichals; palpi dark brown to black. . . . *sylvarum* Meigen

BB. Two post acrostichals; palpi yellow (*caesar*), or brownish (*elongata*).

C. Subcostal sclerite with small black setae; post margin of second tergite with weak appressed bristles. . . . . *caesar* Linne

CC. Subcostal sclerite without setae, post margin of second tergite with strong erect bristles. . . . . *elongata* Shannon

* Nearctic Calliphoridae, Luciliini, Insecutor Inscitiae Menstruus, Vol. XII, Nos. 4–6, 1924, pp. 73–74.

AA. Basicosta yellow.
- B. Two post acrostichals; front above antennae no broader than length of third antennal joint.
  - C. Beard black; facialia setae arranged in a single row. *australis* Towns. and *unicolor* Towns.
  - CC. Beard mostly yellowish; facialia setae arranged in several irregular rows. . . . . *pilatei* Hough
- BB. Three post acrostichals; front above antennae much broader than length of third joint.
  - C. Parafacial broader than parafrontal. . . . . *sericata* Meigen
  - CC. Parafacial as broad as parafrontal. . . . . *pallescens* Shannon

Genus Calliphora

(The Blue Bottle Flies)

These are scavenger flies which deposit their eggs on fresh or decaying meat or on meat which has been cooked. Also on human and animal excrement or in open wounds.

The thorax is bluish black but not lustrous; the abdomen blue and lustrous with white changeable spots.

These flies will come into the house seeking food on which to deposit their eggs. The complete life cycle from egg to adult requires on an average about 22 days; egg stage about 24 hours, larval stage about ten days and pupal stage about eleven days. Pupation takes place in loose earth.

There are several common species of which the *Calliphora vomitoria* and the *Calliphora erythrocephala* are the best known.

Genus Cynomyia

The Genus *Cynomyia* has habits similar to *Calliphora* and closely resembles it but the abdomen is uniformly shining blue without the whitish changeable spots. *Cynomyia cadaverina* Robineau-Desvoidy is a common carrion fly.

Genus Lucilia

(The Green Bottle Flies)

These are also scavenger flies which deposit their eggs on fresh and decaying meat, human and animal excrement and in open wounds.

The thorax and abdomen are metallic green or bluish green and lustrous. The complete cycle of development from egg to adult

requires about two weeks; egg stage one day, larval stage eleven days, pupal stage about twelve days.

Two very common species of *Lucilia* are *Lucilia caesar* and *Lucilia sericata*. The former has a more northern distribution than the latter.

Members of this Genus do not come into the house as frequently as those of the Genus *Calliphora*.

Lucilia sericata and *L. caesar* have been called the "sheep maggot" flies because of the habit of laying their eggs in wounds of sheep or in the soiled wool of sheep especially those having diarrhoea.

Genus Phormia and Genus Protophormia

These flies are also metallic greenish in coloration.

Phormia regina is not unlike *Lucilia* in appearance and habits. *Protophormia terraenovae* has a northern distribution. It is the common scavenger fly of Alaska and also occurs in Greenland and Northern Europe.

Genus Cochliomyia

(The Screw Worm Fly)

(Synonym, *Pycnosoma*, *Chrysomyia*)

Cochliomyia (*Chrysomyia*) *macellaria* Fabricius has a blue-green body, a yellow front to the head and three black lines dorsally on the thorax. It is larger than the common house fly.

It is a danger to man and animals, for although it can not bite, it may deposit its eggs in wounds or in the nostrils or ears, attracted by foul discharges. Sleeping men who have offensive catarrh are especially liable to attack by this fly. The larvae develop quickly and are very destructive eating away the tissue rapidly. Gaining entrance to the frontal sinuses death may result. Several hundred eggs are deposited in rotting flesh, wounds or in body cavities, in the space of a few moments, and several batches may be laid. Eggs develop within a few hours and the larvae grow to maturity rapidly. They pupate in the ground.

This fly is found in tropical and temperate North and South America. In the southern United States it is most prevalent from July to October and is of considerable economic importance as pest of cattle. The larvae have twelve segments with rings of minute spines.

The common means of propagation is probably in the carcasses of dead animals. Proper disposal of such material would go far to eliminate the fly in places where it is a menace.

To dislodge them from the sinuses and ears chloroform is valuable used as a wash of 10% to 25% chloroform in milk.

Genus Bengalia

(Synonym *Ochromyia*)

The larva of this fly burrows under the skin producing a lesion with a central opening somewhat resembling a boil. When mature it drops out and pupates in the ground. Men, monkeys and dogs may be affected. Two species, both African, are known, *Bengalia anthropophaga* and *Bengalia rodhaini*. The larva of the former is known locally as "ver du Cayor."

Genus Auchmeromyia

Auchmeromyia luteola Fabricius is of interest because its larvae live in cracks and crevices in the floors of native huts in tropical and subtropical Africa, coming out at night to suck the blood of persons sleeping on or near the ground. The larva is called the "Congo floor maggot." The adult fly can not bite although it may be a blood feeder. The larva is not known to carry disease.

Genus Protocalliphora

These flies in the larval stage are blood-sucking parasites of nestling birds.

Genus Pollenia

Pollenia rudis is a more or less common fly which breeds in earth worms as a true parasite of the living worm. There are on the thorax a number of soft appressed yellow hairs mixed in with the bristles.

CHAPTER XIII

FAMILY ANTHOMYIIDAE

To this family belong several genera known to be more or less troublesome to man. The arista is naked or pectinate, the first posterior cell is completely open and abdominal bristles are often absent. Eggs are laid on decaying vegetable matter, excrement or on living plants the larvae developing in the roots.

Three genera may be mentioned as follows:

1. Arista bare.......................... *Fannia (Homalomyia)*
2. Arista plumose.......................... *Hylemyia*
3. Arista pubescent.......................... *Hydrotea*

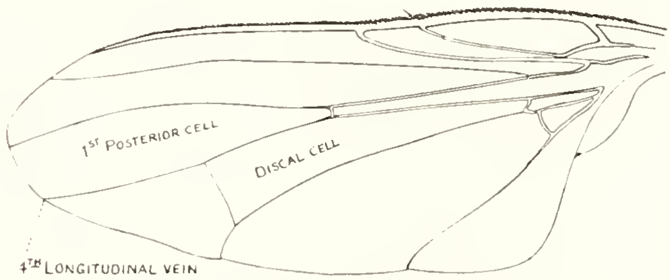

FIG. 51.—Wing of an Anthomyiid fly.

Common species are *Fannia canicularis* or "little house fly" and *Fannia scalaris* or "latrine fly." Superficially these flies resemble the "house fly" but they are smaller and there are but three dark stripes on the thorax instead of four as in *Musca domestica*. They can be differentiated from each other as follows:

1. Sides of second and third abdominal segments translucent yellow in the male.......................... *canicularis*
2. Sides of abdomen blackish, midtibia with a tubercle beyond the middle.......................... *scalaris*

The larvae of *Fannia* are provided with long lateral and dorsal spinous processes which in *F. scalaris* are feathered. (Fig. 50.)

Larvae of *Fannia canicularis* have been passed from the intestines of man, and larvae of *Fannia scalaris* have been passed in the urine.

Anthomyia radicum a root maggot fly of Europe has also been the cause of intestinal myiasis. Because of the habit of developing within roots it is likely that such larvae are frequently taken into the alimentary tract of man when vegetable roots such as radishes are consumed in the raw state. In the United States two of the common root maggot flies are the cabbage root maggot (*Hylemyia brassicae*) and the onion maggot (*Hylemyia antiqua*).

Hydrotea meteorica Linnaeus attacks the eyes and nostrils of animals and man.

CHAPTER XIV

KEY TO THE LARVAE CAUSING MYIASES (ADAPTED FROM BANKS)*

1. Body with spinous or fleshy processes laterally and dorsally or terminal 2
   Body without spinous or fleshy processes 3
2. Body with long lateral and dorsal spinous processes.... *Fannia* (*Homalomyia*.)
   Body with long tail-like process .... *Eristalis*.
   Body ending in two small fleshy processes, rather small species, the processes bearing the stigmal plates, body about 5 mm. long .... *Drosophila*.
   Same but processes not bearing the stigmal plates, body about 10 mm. long. *Piophila*.
3. Body robust, ovate, cylindrical, rounded at ends, slightly depressed, or body pyriform .... Oestridae.
   Body truncate broadly rounded at one end and tapering at the other (head) end 4
4. But one great hook, posterior stigmal plates with winding slits; no distinct lateral fusiform areas, tip of body with few if any conical processes. Muscinae
   With two great hooks; slits in the stigmal plates not sinuous 5
5. No tubercles about anal area; no distinct processes around stigmal field 6
   Distinct tubercles above anal area; often process around stigmal field; lateral fusiform areas usually distinct 7
6. Stigmal plates on black tubercles, lateral fusiform areas distinct. . Ortalidae
   Stigmal plates barely if at all elevated, lateral fusiform area indistinct, stigmal plates often contiguous or nearly so; slits long and subparallel. . Trypetidae
7. Slits in Stigmal plates rather short and arranged radiately 8
   Slits slender and subparallel to each other 9
8. Two tubercles above anal area; stigmal field with distinct fleshy tubercles around it .... Anthomyiidae (except *Faunia*)
   Four or more tubercles above anal area; slits of stigmal plates usually pointed at one end .... Muscina
9. A button to each stigmal plate; slits rather transverse to body. . Calliphoridae
   No button to stigmal plates; slits of one plate subparallel to those in opposite plate; plates at bottom of a pit .... Sarcophagidae

* The Structure of Certain Dipterous Larvae with Particular Reference to Those in Human Food by Nathan Banks, 1912, U. S. Department of Agriculture, Bureau of Entomology. Technical Series No 22.

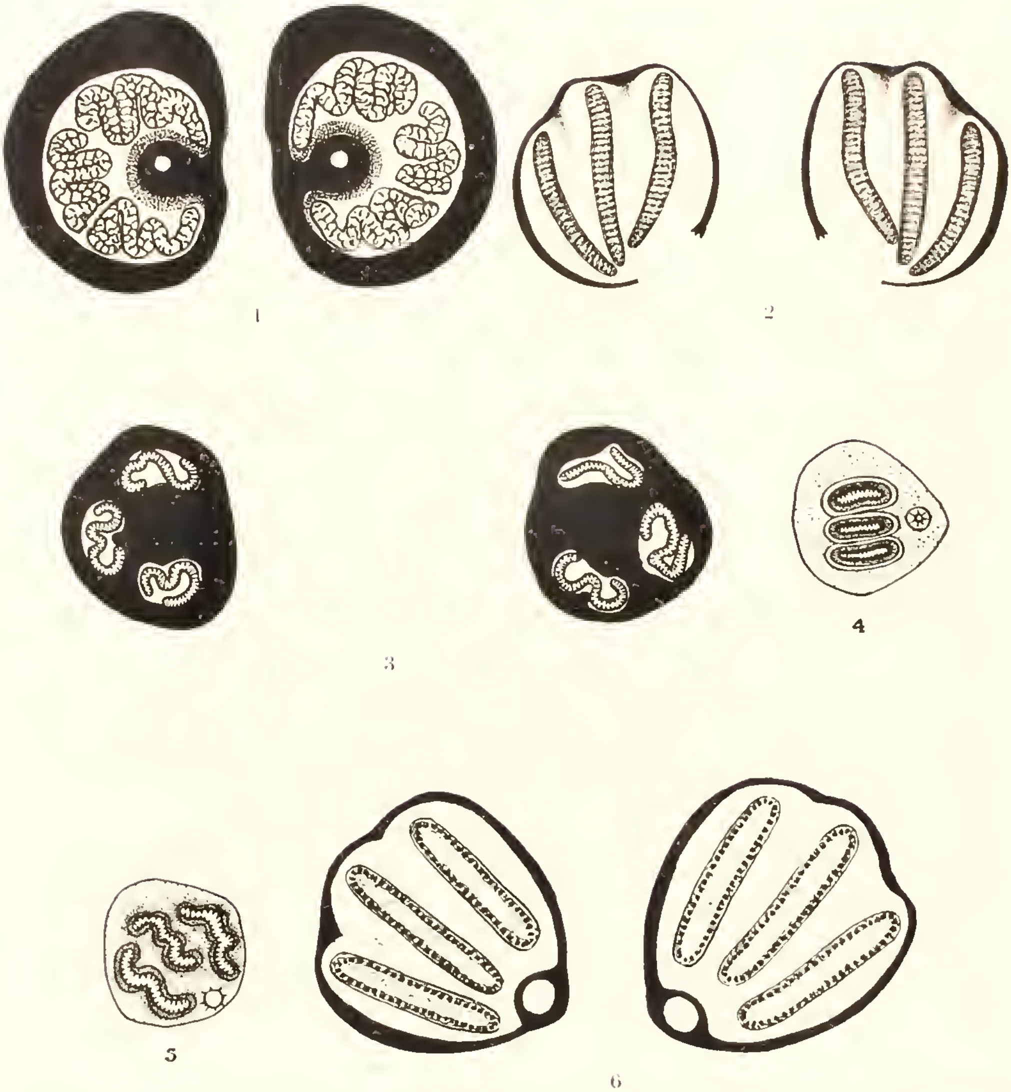

FIG. 52.—Stigmal plates of (1) *Musca domestica;* (2) *Sarcophaga;* (3) *Stomoxys calcitrans;* (4) *Auchmeromyia luteola;* (5) *Bengalia anthropophaga;* (6) *Calliphora.* (4 and 5 are from Stitt and are drawn to a smaller scale than the others; only one plate is shown.)

CHAPTER XV

SUBORDER PUPIPARA

To this Suborder belong certain more or less degenerate blood sucking Diptera with the body depressed dorso-ventrally; the proboscis is concealed, the antennae are reduced; the wings are present or absent when present they may be dropped or very rudimentary; the legs are armed with stout claws and the integument is leathery. Additional claws are often present. The females do not deposit eggs but extrude a larva so far developed that it becomes a pupa in a short time. Some are parasitic on birds and bats, some, the Hippoboscidae, are parasitic on domestic and other animals. A very familiar example of the parasite on a domestic animal is the socalled sheep "tick" or "louse," *Melophagus ovinus* Linnaeus which is a wingless fly almost as dependent on its host as a louse. An example of a winged Hippoboscid is *Hippobosca equina* Linnaeus the forest fly or horse tick as it is sometimes called although it is not a tick at all.

CHAPTER XVI

ORDER SIPHONAPTERA

(Fleas)

Fleas are insects belonging to the Order Siphonaptera. They are wingless and flattened laterally (compressed). The mouth parts are adapted to piercing the skin and sucking blood. The antennae are three-jointed and are carried in a groove on either side of the head; eyes are simple sometimes absent or vestigial. The metamorphosis is complete there being four distinct stages of development, egg, larva, pupa and adult (imago).

Fleas are found on warm blooded animals and birds and in their nests. With certain exceptions each animal has its own particular species of flea, which will only seek the blood of another species of animal when compelled by necessity. Adult fleas subsist on blood and both the males and females bite. The insect infests its host for the purpose of feeding. Copulation may also occur on the host. The eggs develop in the nest, not on the animal, and much of the life history takes place in the nest where temperature and humidity conditions are particularly suited to complete development.

Adult Anatomy. (Fig. 53 and Fig. 54).—Like all insects the body of a flea is divided into a head, thorax and abdomen.

The Head.—The head is divided by the *antennal grooves* into an anterior and a posterior portion known as the *frons* and *occiput* respectively. The lateral lower portion of the head beneath the eye and extending from the anterior angle of the head to the antennal groove, is known as the *gena* and its prolongation backwards as the genal process. This process may extend so far backwards as to meet the occiput thus closing off the antennal groove, or it may be short and widely separated from the occiput thus leaving the antennal groove open behind.

The frons may be notched or tuberculated in front forming the so called *frontal notch* or *tubercle*.

The *antennae*, two in number, one on each side, lie when at rest in the antennal grooves. They are capable of being erected and are

divided into three parts, the distal part or *club* having nine segments. In some species this segmentation does not extend completely around the club.

Just posterior to the anterior inferior angle of the head arises a pair of four-jointed maxillary palpi and posterior to them, one on

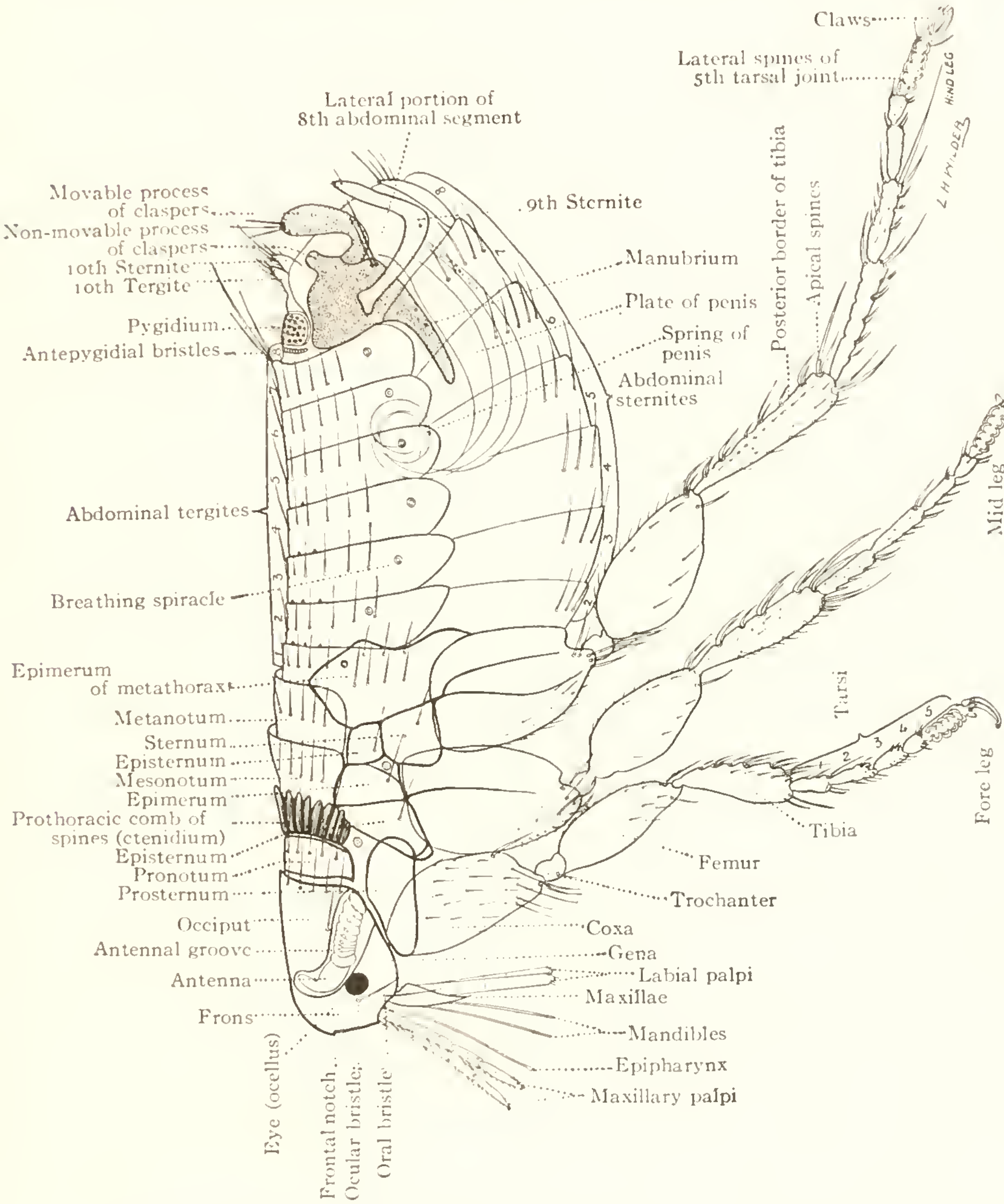

FIG. 53.—The external anatomy of a male flea.

each side are the maxillae,—triangular shaped chitinous processes which serve as a protection to the perioral ring located between them and through which project the mouth parts having their movable articulations attached to its borders.

The mouth parts consist of an *epipharynx* (*labrum-epipharynx*), two *mandibles*, a *labium* and two *labial palpi* (*labellae*). The labial palpi serve as a sheath to protect the epipharynx and mandibles which are the true biting organs. They arise from a common basal joint (the labium) which is attached to the posterior margin of the perioral ring. They are segmented, normally having five pseudo-joints, but the number of segments varies with the species. The labium and labial palpi taken together form the *rostrum*.

The *epipharynx* or pricker is a slender, hollow organ, stylet shaped at its distal extremity. It has an anterior and posterior surface and has at its margins delicate expansions which interlock with similar expansions on the mandibles to form the blood canal. The distal, stylet-like end is closed but the hollow interior communicates proximally with the hoemocoele. The epipharynx is continuous with the anterior wall of the buccal cavity and the dorsal wall of the aspiratory pharynx.

The *mandibles* are triangular on section and have their distal ends serrated. Each is grooved on its inner surface so that when apposed a canal is formed which connects with the salivary pump. This is the *salivary canal*. The mandibles are connected just within the head to the lateral margins of the perioral ring, through the *mandibulo-basal* articulations. Thus a joint is formed giving them an up and down movement and bringing into play the saw-like action of their serrations.

Alimentary Tract. (Fig. 54).—Within the head, above the insertion of the mandibles is the *buccal cavity*. Its posterior wall is thickened and represents the *hypopharynx*. This is concave ventrally and serves as an attachment for the muscles which operate the salivary pump.

Just above the hypopharynx, and connecting it to the aspiratory pharynx, is a thinning and reduplication of the lining chitinous membrane, which serves as a valve. Here begins the *aspiratory pharynx* which leads into the *oesophagus* at the oesophageal commissure of the large nerve ganglion (brain) in the head. The muscles operating the aspiratory pharynx draw it open aspirating the blood from the wound in the skin. When these muscles relax from before backward, the pharynx collapses by reason of the elastic properties of chitin and the blood is forced through the oesophagus and gizzard into the stomach. The muscles have their origins from the inner surface of the dorsal wall of the head.

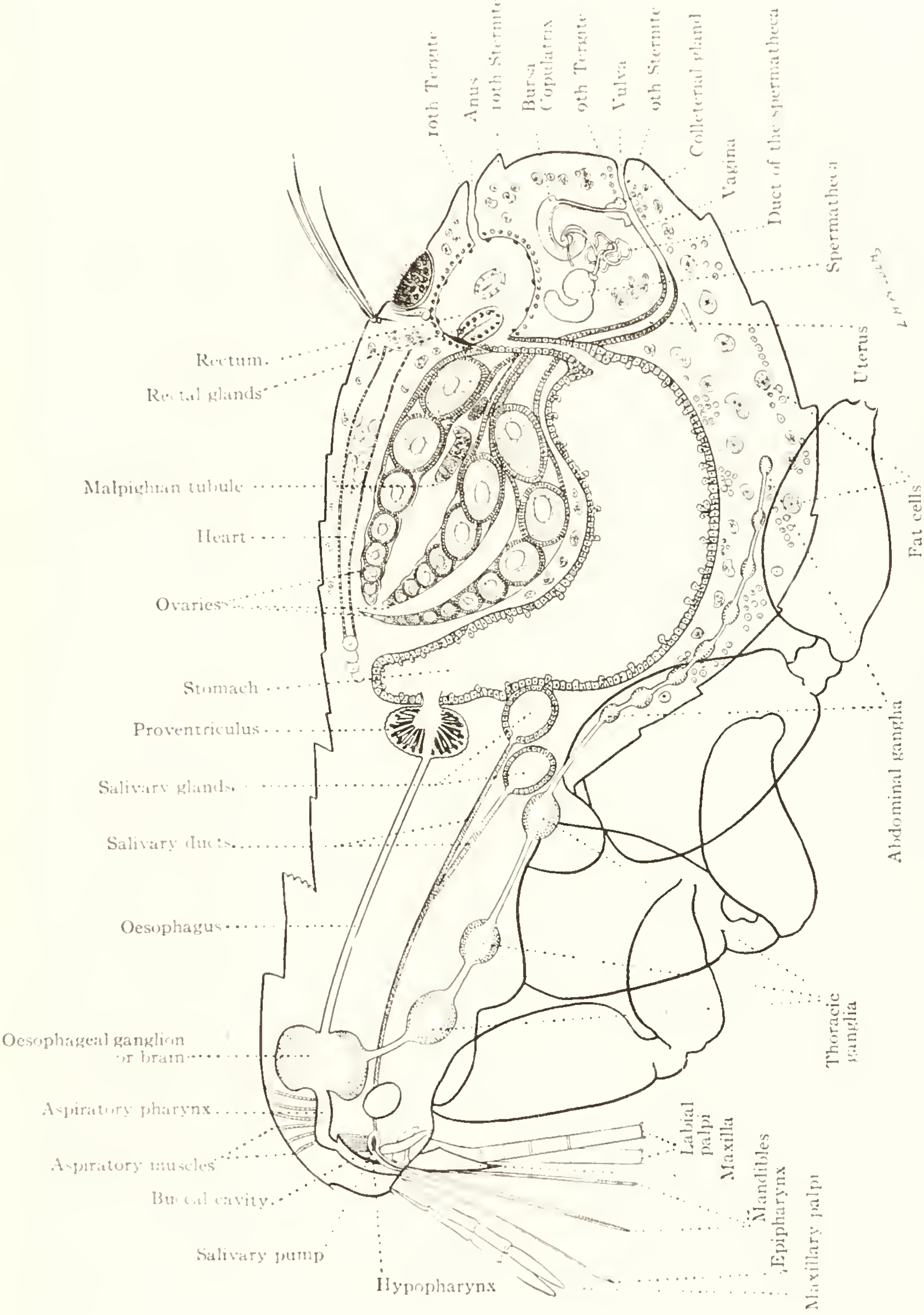

FIG. 54.—The internal anatomy of a female flea.

The oesophagus opens into the stomach through the gizzard (proventriculus). This is provided with a number of chitinous finger-like processes which when apposed form a tight valve preventing regurgitation from the stomach. The *stomach* is capable of great distension and active peristaltic movement. It is not lined with chitin. It empties into a short *intestine* which in turn empties into the *rectum*. The intestine receives the excretions from the *Malpighian tubules*. The rectum is provided with the so-called rectal glands the function of which is unknown.

The *salivary glands*, four in number, lie two on each side of the anterior end of the stomach. They are simple ascinous glands and their ducts unite into two main ducts which empty into the salivary pump in the head. The ducts are lined with chitin spirally arranged.

The Thorax.—The three thoracic segments are known as the *pro, meso* and *metathorax*. Each is formed of a dorsal portion the *notum* or *tergite*, and a ventral portion, the *sternite*. The prosternite is undivided but the lateral portions of the meso- and metasternite are divided by an internal rod-like thickening of the chitin extending upward from the insertion of the coxa, into an anterior and a posterior part, the *sternal* and the *meral* portion or *epimerum*. The sternal portion is further divided into a lower part the sternum and an upper part, the episternum. The epimerum of the metathorax is broad, overlapping the abdomen and supplanting the sternite of the first abdominal segment. There is a breathing spiracle on both sides of each thoracic segment the third being located at the upper edge of the metathoracic epimerum.

The Abdomen.—The abdomen is made up of ten segments. Each consists of a dorsal portion or *tergite* and a ventral portion or *sternite*. On each side of abdominal segments 2 to 7 is a *breathing spiracle*, located in the pleural membrane connecting the tergite with the sternite.

The seventh tergite usually has on or near its apical margin (dorsally) on each side, one or more stout bristles sometimes arising from a cone-like process. These are known as the *antepygidial bristles*. Posterior to them is a sensory organ known as the *sensory plate* or *pygidium*. It is present in both males and females and its function is unknown. It is carried on the dorsal portion of the ninth tergite. It is separated from the seventh tergite by the dorsal part of the eighth tergite which contains the eighth or last breathing spiracle. The lateral portion of the eighth tergite is expanded on

each side into a broad lobe which in the female conceals the ninth segment in relation to the genital orifice.

The clasping organs of the male which are developed from the ninth abdominal segment are characteristic of the species and are therefore of great taxonomic value. They are divided into the *upper* and *lower claspers*. In general the upper claspers, which are evolved from the 9th. tergite, consist of a pair of movable processes each articulated to a more or less broad irregularly shaped plate. The plate consists of a body and a long process extending caudoventrad and known as the *manubrium*. Above and anterior to the insertion of the movable finger or expodite, the body is usually prolonged into a more or less cone-like process (sometimes two) which may be termed the *immovable process*. In some species, there may be two or more movable processes, as in *Pulex irritans* in which the claspers resemble a pair of pincers covered by a hairy movable flap; or, as in *Xenopsylla* where there are three processes, two movable and one immovable. These correspond to the jaws of the pincers and the flap of *P. irritans*. The *lower clasper* is evolved from the 9th. sternite. In general it has the shape of a boomerang on side view. It is made up of an external horizontal arm and an internal vertical arm. The latter extends upward to the base of the manubrium lying on its outer side. The horizontal arm may project distally from the end of the abdomen and is sometimes fused with its fellow of the opposite side. It is between the upper and lower claspers that the male organ is projected during the act of copulation.

The *vulva* of the female is also found between the 9th. tergite above and the 9th. sternite below. The *anus* in both sexes is found between the 10th. tergite and the 10th. sternite. The latter are seen as two small flaps posterior to the pygidium. The upper flap or 10th. tergite of the female has a small bristled process known as the *style*.

In the female certain of the accessory organs of reproduction are, in shape, as characteristic of the species as are the clasping organs in the male. This is especially true of the *spermatheca* or *receptaculum seminis* which is the resevoir in which the spermatozoa are stored until the egg is in a position to be fertilized as it passes down the egg canal. The spermatheca is readily recognized as a highly chitinized organ located in the posterior part of the abdomen. It is made up of a body and a tail. The body connects by an elongated, tortuous tube, the *ductus receptaculi seminis*, to the *bursa*

copulatrix, which in turn opens into the vagina. Just posterior to this opening are the *colleterial glands* which by their secretion give hardness to the egg.

Legs.—The flea, as other insects, has three pairs of legs. The hind legs are noticeably the largest. Each is composed of a coxa, trochanter, femur, tibia and a five-segmented tarsus, the last tarsal segment terminating in a pair of claws.

Fleas are provided with spines, or spinelets and setae (bristles or hairs). They vary in number and arrangement and are important structures in identification. The spines are frequently disposed so as to form a ctenidium or comb on the head, thorax or abdomen.

The Egg.—The egg is a tiny, elongated, white, glistening body, viscous or dry depending on the species. Blood seems to be neces-

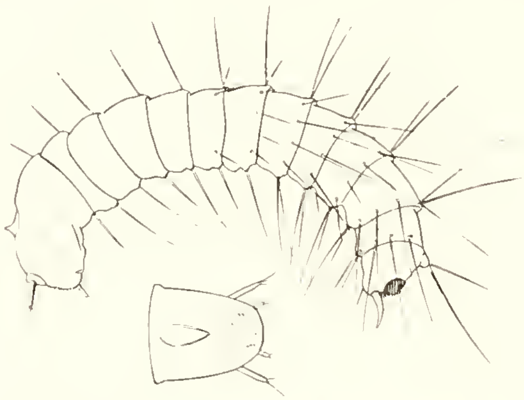

FIG. 55.—A flea larva (*Ctenocephalus canis*).

sary before oviposition can take place. Blood of the normal host seems to be most conducive to egg laying. High temperatures as body temperature prevent hatching; low temperatures either delay or prevent it. The length of time required to hatch therefore varies with the temperature as well as with the humidity and therefore varies under different climatic conditions. Observers in India found that the incubation period for eggs of the Indian rat flea was 2 days. In San Francisco, California, it was found to be 9 to 13 days at room temperature. In the same place and under similar conditions it was found that the eggs of the human flea took 6 days to hatch, eggs of the dog flea about 4 days, eggs of the California ground squirrel flea 7 to 8 days and of the European rat flea 5 to 6 days.

Larva. (Fig. 55).—The larva emerges from the egg by making a circle of gashes in the egg shell with a wedge-shaped horny structure

on its head. The larva is a slender, legless, worm-like creature with masticatory mouth parts. Larval fleas feed on the organic matter in the dust of the floors, carpets, etc. or in the nest of the animal. An important source of food supply seems to be the excreta of adult fleas.

Pupa.—After a period varying from one to four weeks during which time it undergoes three moultings, the larva spins a cocoon and becomes a quiescent pupa, which in from one to four weeks becomes the fully grown and fully developed adult flea.

CLASSIFICATION

The Order Siphonaptera is divided into two Suborders,—the Fracticipita and the Integricipita. In the Suborder Fracticipita (Figs. 56 and 57) the frons and occiput are separated dorsally by

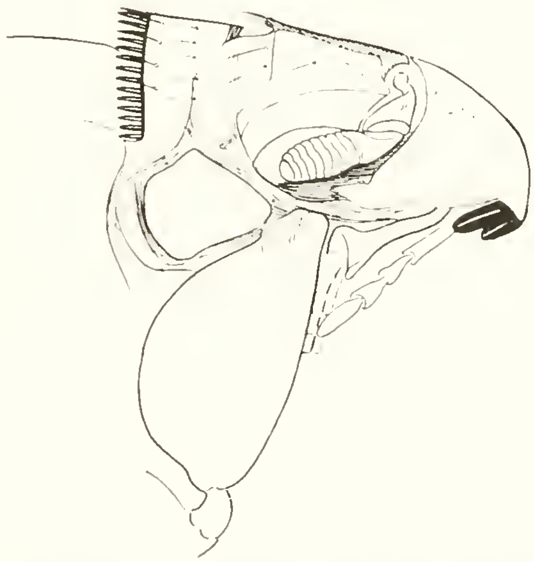

FIG. 56.—Head of a bat flea (*Ischnopsyllus octactenus*).

a sulcus through the chitinous envelope of the head, extending from the top of the antennal groove of one side, across the vertex to the antennal groove of the other side. A joint is thus formed which permits of some motion between the frons and occiput, the former overlapping the latter above. The antennal groove is a part of the occiput and its thickened posterior margin after contouring the groove above turns abruptly towards the vertex.

In the Suborder Integricipita (Figs. 61 and 65) the frons and occiput have fused together, the line of union or suture being often visible as a chitinous thickening extending to the top of the head.

This thickening is known as the *falx*. The anterior and posterior margins of the antennal groove have also coalesced above.

There are certain genera which seem to represent a transitional stage (connecting link) between the two groups,—from the Fracticipita to the Integricipita—the former being the primitive form. Fusion between the frons and occiput has progressed to a more or less degree and the joint is vestigial. Under such circumstances there might be a difference of opinion as to which group a given specimen should be assigned so that in using the following key it would be well to try both Suborders when one has failed to produce results.

The Order is also subdivided into a number of families, including Tungidae, Pulicidae, Ceratophyllidae, Leptopsyllidae, Hystrichopsyllidae, etc.

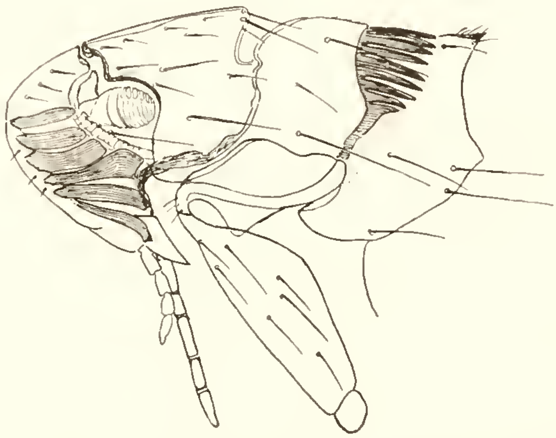

FIG. 57.—Head of a Fracticipite flea (*Corypsylla ornatus*).

Key to the Genera of the Siphonaptera

1. Frons and occiput separated above by a sulcus extending from the top of the antennal groove of one side, across the vertex to the antennal groove of the other side; anterior and posterior margins of antennal groove not fused above the root of first antennal segment; lateral apical spines or spinelets often present on some of the abdominal segments, extending to or almost to the stigmata.......(Suborder Fracticipita)..46

   Frons and occiput not separated by a sulcus; falx often present; anterior and posterior margins of antennal groove fused above root of first antennal segment; apical spines never present, apical spinelets when present usually dorsal rarely extending to the stigmata (Suborder Integricipita)...2

2. The three thoracical tergites together always shorter than the first abdominal tergite; no comb present; the rostrum consists of three, or fewer, feebly chitinized segments; genal edge of head in all cases produced downwards into a triangular lobe situated behind the mouth parts................3

Thoracical tergites together longer than the first abdominal tergite; combs of spines frequently present; rostrum more or less strongly chitinized, consisting of four or more segments (rarely less); lower edge of head rarely produced into a triangular lobe behind the mouth parts. 5

3. Hind coxa without a patch of spinelets on the inner side. 4

Hind coxa with a patch of spinelets on the inner side (Fig. 59).
* *Echidnophaga* Olliff (1886) (*ambulans*)†

4. Hind femur simple without a large tooth-like projection near the base (Page 130). . . . . * *Tunga* Jarocki (1838) (*penetrans*)

Hind femur with a large tooth-like projection near the base.
* *Hectopsylla* Frauenfeldt (1860) (*psittaci*)

5. Abdominal tergites two to seven with but one row of bristles. 6

Abdominal tergites two to seven with at least two rows of bristles. 22

6. With a row or patch of spinelets on inner side of hind coxa; antepygidial bristles one on each side; four (rarely three) pairs of lateral plantar bristles on fifth tarsal segment of all legs. 7

Without a row or patch of spinelets on inner side of hind coxa. 18

7. Eye absent. . . . . *Rooseveltiella* Fox (1914) (*georychi*)

Eye present 8

8. No pronotal comb. 9

Pronotal comb present, of few or numerous teeth. 14

9. Anterior angle of genal edge produced into a lobe 10

Anterior angle of genal edge not produced into a lobe. 11

10. Frons with very small frontal tubercle near the vertex; anterior angle of genal edge of head produced downwards into a triangular lobe; pronotum shorter than metanotum. . . . . *Mocopsylla* Rothsch. (1908) (*sjoestedti*)

Frons without tubercle; anterior angle of genal edge of head produced backwards into a triangular lobe; pronotum longer than metanotum.
Pariodontis Rothsch. (1908) (*riggenbachi*)

11. Mesosternite very narrow, with but one internal rod-like incrassation which extends from the insertion of the coxa forward to the anterior border (Fig. 60). . . . . * *Pulex* Linnaeus (1758) (*irritans*)

Mesosternite with two internal rod-like incrassations, one extending from the insertion of the coxa forwards and one extending upwards. 12

12. Frontal tubercle present; frons strongly angulate in male more evenly rounded in female. . . . . *Ornithopsylla* Rothsch. (1908) (*laetitiae*)

No frontal tubercle; frons not angulate, strongly rounded in both sexes. . 13

13. Fifth tarsal segment of all legs with three pairs of lateral plantar bristles; club of antenna plainly segmented all around.
Actenopsylla J. & R. (1923) (*suavis*)

Fifth tarsal segment of all legs with four pairs of lateral plantar bristles; club of antenna distinctly segmented only on hind side (Fig. 61).
* *Xenopsylla* Glink. (1907) (*cheopis*)

* A star in front of the generic name indicates that the genus is found in the New World.

† The specific name following the date is the type of the genus.

14. With a comb of spines on the pronotum only (Fig. 64).
** Hoplopsyllus* Baker (1905) (*anomalus*)
With a comb of spines on the pronotum and the gena..................15
15. Spines in genal comb numerous (more than three)......................16
Spines in genal comb reduced to three or less; pronotal comb also reduced.
Archaeopsylla Dampf (1908) (*erinacei*)
16. Genal comb running horizontally along lower border of gena; teeth of comb consisting of about seven rather long, pointed spines (Fig. 63).
** Ctenocephalus* Kolenati (1859) (*canis*)
Genal comb running across gena obliquely............................17
17. Mandibles large, strongly serrated; frons tending to be obtusely angled in front..........................* *Spilopsyllus* Baker (1905) (*leporis*)
Mandibles not enlarged; frons rounded.
Nesolagobius J. & R. (1922) (*callosus*)
18. Pronotal comb present...... 19
Pronotal comb absent............ 20
19. Labial palpus of five segments, the last segment very long, slightly curved at the apex, much more produced posteriorly than anteriorly
**Megarthroglossus* J. & R. (1915) (*procus*)
Labial palpus of four segments, not as above; second segment of antenna widened on outside, covering one-third of the club
**Callistopsyllus* J. & R. (1915) (*terinus*)
20. Eyes absent; fifth hindtarsal segment with four pairs of lateral plantar bristles; one antepygidial bristle on each side; vestiture of body greatly reduced.....................**Anomiopsyllus* Baker (1904) (*nudatus*)
Eyes present... 21
21. Frons with a tooth-like tubercle; antennal groove closed behind; antepygidial bristles absent in both sexes; fifth tarsal segment of all legs with six (rarely five) pairs of lateral plantar bristles.
Lycopsylla Rothsch. (1904) (novus)
Frons truncate with no distinct frontal tubercle; antennal groove open behind; antepygidial bristles two on each side, a long and a short one; fifth tarsal segment of all legs with five pairs of lateral plantar bristles; two receptacula seminis; claws of tarsi with basal tooth.
Coptopsylla Rothsch. (1908) (*lamellifer*)
22. Genal comb present...23
Genal comb absent..29
23. Eye present but not always strongly pigmented; spines of genal comb two either parallel or crossing each other..............................27
Eye absent or vestigial; spines of genal comb three (rarely two) or five or six in number.. 24
24. Metasternite not divided; 5 spines in genal comb, the third one pale and overlapping the second; a small flea.
* *Micropsylla* D. & P. (1925) (*peromyscus*)
Metasternite normally divided; none of the genal spines overlapping; labial palpus with a curved bristle posteriorly near the tip....... 25

25. Spines of genal comb three (rarely 2); fifth hind tarsal segment with three pairs of lateral plantar bristles and a fourth pair on the ventral surface in between the first lateral pair (rarely four pairs of lateral bristles). * *Ctenophthalmus* Kolenati (1856) (*bisoctodentatus*)

Spines of genal comb five 26

26. Fifth tarsal segment of all legs with four pairs of lateral plantar bristles. * *Rhadinopsylla* J. & R. (1912) (*musculana*)

Fifth tarsal segment of all legs with six pairs of lateral plantar bristles. * *Actenophthalmus* Fox (1925) (*heiseri*)

27. Genal spines two crossing each other; fifth tarsal segment of all legs with four pairs of lateral plantar bristles; antepygidial bristles one on each side. *Chiastopsylla* Rothsch. (1910) (*numae*)

Genal spines two parallel to each other 28

28. Bristles on posterior border of tibiae mostly unpaired, numerous, forming a kind of comb; spines in pronotal comb deflected; pronotum much wider above than at the sides.......... *Caenopsylla* Rothsch. (1909) (*mira*)

Bristles on posterior border of the tibiae mostly in pairs; spines of pronotal comb not deflected; blunt; eye large; apical margin of pronotum incurved. *Mesopsylla* Dampf (1910) (*eucta*)

29. With a row or patch of spinelets on inner side of hind coxa............ 30

Without a row or patch of spinelets on inner side of hind coxa.......... 31

30. Without oblique rows of bristles on occiput; eye present; fifth tarsal article of all legs with five pairs of lateral plantar bristles. * *Odontopsyllus* Baker (1905) (*multispinosus*)

With oblique rows of bristles on occiput; eye vestigial; fifth article of fore and mid-tarsus with four pairs of lateral plantar bristles and a proximal ventral pair in between the first lateral pair, fifth tarsal segment of hind leg with four pairs of lateral plantar bristles, the ventral pair being absent or represented at the most by one bristle. * *Catallagia* Rothsch. (1915) (*charlottensis*)

31. Fifth tarsal article broadly dilated and lengthened beyond the fourth pair of lateral spines where on each side there is a hair, a bristle and a hair, there is also a pair of subapical bristles; fifth tarsal segment of fore leg as long as rest of tarsus; on all legs the claws are nearly as long as the fifth segment; fore coxa nearly nude with but few long bristles; fore tibia armed on posterior border with a few large black tooth-like bristles or a few heavy bristles........* *Malacopsylla* Weyenbergh (1881) (*grossiventris*)

Legs not as above 32

32. Frontal notch or tubercle present; with or without eye 33

No distinct frontal notch or tubercle; eye present 41

33. Fifth tarsal segment of all legs with four pairs of lateral plantar bristles, never with a pair of proximal ventral bristles; antepygidial bristles 0 or 1; no pronotal comb; eye present 34

Fifth tarsal article of all, or at least some of the legs, with five pairs of plantar bristles, all lateral, or four lateral and a proximal ventral pair 37

Fifth tarsal segment of all legs with six pairs of lateral plantar bristles all in line except the third pair which is dislocated towards the median line; pronotal comb present; one antepygidial bristle on each side.

* *Dasypsyllus* Baker (1905) (*perpinnatus*)

34. Antepygidial bristles none; an eye row of four or five long bristles; claspers broad and deep, disc-like; species usually very hairy..................35

Antepygidial bristles one on each side; an eye row of three bristles or less; claspers large, triangular; species not especially hairy..................36

35. Club of antenna short, symmetrical, not much longer than broad; labial palpus of about eleven segments; body of pregnant female elongate.

Vermipsylla Schimk (1885) (*alacurt*)

Club of antenna long; labial palpus of from five to seven segments; gena often dark, blending with eye.

* *Trichopsylla* Kolenati (1863) (*penicilliger* Kolenati)

36. Club of antenna short, not symmetrical, the proximal segments sloping backwards; segmental incisions most marked on hind side; genal process with only two bristles behind eye, one at some distance above other.

* *Rhopalopsyllus* Baker (1905) (*lutzi*)

Club of antenna long, symmetrical; segmental incisions marked on both sides; genal process with several bristles along lower margin or at least one or two bristles close behind eye.

* *Parapsyllus* Enderlein (1903) (*longicornis*)

37. Maxillary palpus very long and slender reaching beyond the apex of the fore coxa and being longer than the labial palpus which is five segmented; the bristles of the postmedian row on the abdominal segments and metanotum are long, generally of nearly the same width to near the tip or even slightly widened distally, the tip not drawn out into a long thin point; antepygidial bristles one; eye vestigial.

Xiphiopsyllus J. & R. (1913) (*hippia*)

Maxillary palpus not reaching beyond the apex of forecoxa; bristles of abdomen and metanotum normal in contour (drawn out into a fine point). 38

38. Frons with a large spade-shaped tubercle; eye small, behind same a bristle-like spine; some spinelets on first five abdominal segments.

Listropsylla Rothsch. (1907)(*agrippinae*)

Frontal tubercle present but not so prominent; no bristle-like spine back of eye; with or without dorsal spinelets on abdominal segments.........39

39. Antepygidial bristles 4 or 5 (rarely 3) on each side; a lower genal row of five bristles; eye absent; five pairs of lateral plantar bristles on fifth tarsal segment of all legs, the first pair somewhat dislocated towards the median line; especially prominent in the male is a median caudal extension of the seventh tergite between the two groups of antepygidial bristles; occiput with an oblique row of bristles

* *Dolichopsylla* Baker (1905) (*stylosus*)

Antepygidial bristles three on each side, in the male one or two of them frequently reduced in size; a lower genal row of about three bristles...40

40. Head with three rows of bristles across frons and occiput; eye reduced; bristles of second antennal segment short in both sexes; hind margin of pronotum slightly incurved; mid- and hind tibiae with two to four single dorsal bristles in between the postmedian and subapical dorsal pairs; bristles of tarsi short, fifth segment with the first pair of plantar bristles moved on to the ventral surface; clasper of male without a bristle at the insertion of the movable process; ventral arm of ninth sternite without a sinus; eighth sternite large, in the female with an oblique vertical row of bristles.................* *Amphipsylla* Wagner (1909) (*shelkovnikovi*).

Bristles on occiput rarely tending to form oblique rows; one or two rows of bristles on frons; eye present (rarely absent); some of the bristles on the second joint of antenna frequently as long as or longer than the club; hind margin of pronotum not incurved; most of the bristles on hind margin of tibiae in pairs; some of the apical bristles on second hind tarsal segment often long at times reaching well to the fifth segment; five pairs of lateral plantar bristles on the fifth tarsal segment of all legs, the first pair at times bent or dislocated towards the median line or even moved well on to the ventral surface; clasper of male with two bristles at the insertion of movable process; ventral arm of ninth sternite with a sinus; eighth sternite small, and in the female with no distinct vertical row of bristles (Fig. 65)............* *Ceratophyllus* Curtis (1832) (*hirundinis*)

41. No antepygidial bristles; ventral margin of head dilated behind the palpus into a rounded lobe projecting downwards; genal process immediately behind eye dilated into a truncate flap which partly covers the club of the antenna; pronotum almost hammer-shaped; episternum of metathorax larger than sternum; eye large.... *Uropsylla* Rothsch. (1905) (*tasmanicus*)

Two antepygidial bristles on each side; head and thorax not as above; pygidium usually convex; species hairy..........................42

42. Pronotal comb absent; antennal groove open behind.
Notiopsylla J. & R. (1914) (*kerguelensis*)

Pronotal comb present; antennal groove closed behind; eighth abdominal sternite of male very large...................................43

43. Pronotum with one row of bristles; hind tibia with one lateral row on outer surface.........................*Choristopsylla* Rothsch. (1922) (*ochi*)

Pronotum with at least two rows of bristles..........................44

44 Comb incomplete, reduced to a small number of spines.
Bradiopsylla Rothsch. (1922) (*echidnae*)

Comb complete, with more than sixteen spines on the two sides together..45

45. Frons without a pair of short stout spines in the first row of bristles; expodite (movable process) of male very long, curved down at the apex; female with conspicuous process dorsally between the two pairs of antepygidial bristles...................... *Stivalius* Rothsch. (1922) (*ahalae*)

Frons as in *Stivalius;* expodite of male curved up at apex; female without dorsal process between antepygidial bristles.
Pygiopsylla Rothsch. (1906) (*hilli*)

Frons with two short, stout, curved spines in the anterior row of bristles.
Acanthopsylla Rothsch. (1922) (*rothschildi*)

46. Head with two chitinous flaps anteriorly on each side (the bat fleas) (Fig. 56) 70
Head without these flaps but often with a genal comb of strongly chitinized spines 47

47. A comb of numerous spines on the frons placed around the border of a "cap" or "crown" which is divided off from the rest of the frons by a marked suture; genal comb present or absent 48
No such arrangement of frontal spines; with or without genal comb 50

48. Cap vertically placed or nearly so; genal comb present 49
Cap horizontally placed; genal comb absent.
Stephanopsylla Rothsch. (1911) (*thomasi*)

49. No row or patch of spinelets on inner side of hind coxa; maxilla elongate, triangular .... *Stephanocircus* Skuse (1893) (*dasyuri*)
A patch of spinelets on inner side of hind coxa; maxilla irregularly elongate*l*. ovate, tip somewhat pointed... **Craneopsylla* Rothsch. (1911) (*wolffhuegeli*).

50. With lateral apical spines or spinelets on some of the abdominal segments reaching to or almost to the stigmata 51
Without lateral apical spines or spinelets on the abdominal segments; dorsal apical spinelets frequently present 57

51. Eye present or somewhat reduced; abdominal combs of spines or spinelets not so conspicuous; bristles on posterior border of tibiae mostly in pairs... 52
Eye absent or vestigial; abdominal combs of spines or spinelets usually conspicuous; some of the bristles on posterior border of hind tibia in groups of three (or four), or at times single forming a kind of comb; notch at apical end of hind coxa usually very pronounced 53

52. Genal comb of five or six spines; labial palpus of four segments; eye well defined .... *Typhloceras* Wagner (1903) (*poppei*)
Genal comb absent; labial palpus of six to eight segments; eye reduced.
**Atyphloceras* J. & R. (1915) (*multidentatus*)

53. Genal process broad and obtuse and separated from the oral edge by a deep sinus; frontal spines arranged along the anterior edge of antennal groove; first segment of antenna large, as long as the club, second segment short except on the anterior side where it is much produced distad; bristles on posterior border of tibiae mostly single forming a kind of comb; one receptaculum seminis....... *Dinopsylla* J. & R. (1913) (*ellobius*)
Genal process not separated from the oral edge by a deep sinus; first and second segments of the antenna not as above; some of the bristles on posterior border of hind tibia in groups of three (or four); a comb of spines along ventral edge of gena and at times along the anterior border of antennal groove; receptaculum seminis frequently double 54

54. Five pairs of lateral plantar bristles on fifth tarsal segment of all legs; labial palpus of four or five segments; two receptacula seminis 55
Four pairs of lateral plantar bristles on fifth tarsal segment of all legs with a ventral pair placed in between the first lateral pair; labial palpus with one or 11 to 13 segments; receptaculum seminis one or two 56

55. Frons rounded as far down as first genal spine; a comb of spines along ventral edge of gena; abdominal tergites with two rows of bristles.
** Ctenoparia* Rothsch. (1909) (*inopinata*)

Rounding of frons stopping well above first genal spine; a comb along ventral edge of gena the middle spine being the longest; abdominal tergites with three rows of bristles . . . .* *Hystrichopsylla* Taschenberg (1880) (*talpae*)

56. Labial palpus of one segment; a comb of spines on ventral border of gena; one receptaculum seminis . . .* *Stenoponia* J. & R. (1911) (*tripectinata*)

Labial palpus of 11 to 13 segments; a comb of spines along ventral border of gena as well as along antennal groove; chitin of occiput internally thickened at about the middle; two receptacula seminis of unequal size.
Macropsylla Rothsch. (1905) (*hercules*)

57. Mandibles and labrum-epipharynx very broad particularly the former; labial palpus but feebly chitinized and showing but three distinct segments; six genal spines in vertical row; one antepygidial bristle; row of spinelets on inner side of hind coxa....*Chimacropsylla* Rothsch. (1911) (*potis*)

Mandibles and labrum-epipharynx slender; labial palpus well chitinized and distincly showing four or more segments..... 58

58. Frons often narrowly rounded (subangulate) in front; bristles on posterior border of tibiae mostly single forming a kind of comb; four pairs of lateral plantar bristles on fifth tarsal segments of all legs with or without a ventral pair in between the first lateral pair................................59

Bristles on posterior border of tibiae mostly in pairs and not forming a kind of comb....... 61

59. Frons subangulate with short stout spiniform bristles near anterior margin; with or without genal comb; eye absent or vestigial.................60

Frons not subangulate. and without spiniform bristles near anterior margin: genal comb vertical with the teeth of the comb rounded at the tip and somewhat overlapping anterior edge of antennal groove; eye near base of antenna; a comb or patch of small spiniform bristles on inner side of hind coxa; four pairs of lateral plantar bristles on fifth tarsal segment of all legs.......................*Hypsophthalmus* J. & R. (1913) (*campestris*)

60. Genal comb present, vertical, of from two to numerous teeth; frons subangulate in front, with two or three spine-like bristles near the angle; labial palpus of five segments; four lateral pairs of plantar bristles with a pair of ventral bristles in between the first lateral pair (Fig. 67).
* *Leptopsylla* J. & R. (1911) (*musculi*)

Genal comb absent; frons strongly subangulate with tubercle at the angle; a row of spiniform bristles parallel with margin of frons from oral corner to base of antennal groove; second segment of antenna widened apically into a broad rounded lobe covering in the male one-third the club, in the female one-half; labial palpus of four segments.
* *Stenistomera* Rothsch. (1915) (*alpina*)

61. With two combs of spines on the head a frontal and a genal, the frontal comb not placed around the borders of a cap or crown which is divided off from the rest of the frons by a suture; frons strongly reclining backwards; two antepygidial bristles on each side; occiput with an internal dorsal incrassation before the centre.
Cleopsylla Rothsch. (1914) (*townsendi*)

With but one comb of spines on the head.......................... ...62

62. Genal comb of two spines either parallel or crossing each other.........63

Genal comb of three spines, quite small and pale; no genal process; antepygidial bristles one on each side placed at some distance from the apical margin of the seventh tergite; eye strongly reduced.
Agastopsylla J. & R. (1923) (*boxi*)

Genal comb of four spines...65

Genal or frontal comb of five or six spines.................................67

63. Genal spines crossing each other...64

Genal spines parallel to each other; eye reduced, not pigmented; frons produced into a kind of snout at a short distance from the maxillary palpus..........................*Acropsylla* Rothsch. (1911) (*episema*)

64. Frontal tubercle absent; without dorsal spinelets on the abdominal segments; fifth segment of tarsi on all legs with four pairs of lateral plantar bristles and a ventral pair in between the first lateral pair; hind coxa with a row or patch of small bristles on the inner surface.
* *Phalacropsylla* Rothsch. (1915) (*paradisea*)

Frontal tubercle present, small; with dorsal apical spinelets on some of the abdominal segments; five pairs of lateral plantar bristles on fifth fore and mid-tarsal segment, on the fifth hind tarsal segment the proximal pair placed ventrally between the first lateral pair or, the proximal pair ventrally placed between the first lateral pair on all legs; a patch of spinelets or thin bristles on inner side of hind coxa.
* *Neopsylla* Wagner (1902) (*bidentatiformis*)

65. First spine of genal comb almost completely covered by second; antepygidial bristles two on each side; eye without pigment.
Neotyphloceras Rothsch. (1914) (*rosenbergi*)

First spine of genal comb not covered by second.......................66

66. Labial palpus of four segments; the genal spines of almost equal length, second from above not sharply pointed; two or three antepygidial bristles on each side..............* *Doratopsylla* J. & R. (1912) (*dasycnemus*)

Labial palpus of five segments; second spine from above long and tapering to a sharp point.................*Palaeopsylla* Wagner (1902) (*minor*)

67. Hind coxa with a row or patch of spinelets (or spiniform bristles) on the inner side..68

Hind coxa without a row or patch of spinelets on inner side; no frontal notch or tubercle; head rounded; fifth tarsal segment of all legs with four pairs of lateral plantar bristles and one ventral pair in between the first lateral pair; genal spines similar to *Nearctopsylla*. (See 69.)
Chiliopsylla Rothsch. (1915) (*allophyllus*)

68. Eye present placed high up in head near base of antenna; genal process deep with a vertical genal comb of about five spines extending from eye to ventral border of head; one long antepygidial bristle accompanied by two very small ones; fifth segment in all tarsi with four pairs of lateral plantar bristles................*Hypsophthalmus* J. & R. (1913) (*campestris*)

Eye absent...69

69. Genal spines six, all more or less elongated, the fourth from top dilated at the tip; abdominal tergites 1 to 7 with an internal thickening dorsally; frons subangulate; genal process, short, truncate. (Fig. 57.)
* *Corypsylla* Fox (1908) (*ornatus*)

Genal spines five, the upper one short, broad and triangular, the next three lanceolate, the fourth (2nd. from below) the longest; abdominal tergites without dorsal internal thickening; frons rounded; pronotal comb curved frontad ventrally.... .... ..* *Nearctopsylla* Rothsch. (1915) (*brooksi*)

70. Maxilla acuminate. 71

Maxilla truncate..... 75

71. One or more of the abdominal tergites with a comb of spines...........72

Abdominal tergites without combs, with a pair of dorsal spinelets; eye bristle present; antepygidial bristle present; genal process acuminate.
* *Sternopsylla* J. & R. (1921) (*texanus*)

72. Head very short, semicircular; first abdominal tergite with comb; prothorax, apart from comb, extremely short; bristles on posterior border of tibiae of an even length forming a kind of comb.
Thaumapsylla Rothsch. (1907) (*breviceps*)

Head elongate, distinctly longer than deep.........................73

73. Frons with distinct tubercle; first abdominal tergite with small comb, tergites II to VI and metanotum with a few short apical teeth; bristles on posterior border of tibiae in pairs not forming a kind of comb; fifth tarsal segment with first pair of plantar bristles replaced by small ventral bristles.
* *Ptilopsylla* J. & R. (1921) (*leptina*)

Frons without tubercle; eye bristle absent; abdomen with four combs....74

74. Second segment of antenna enlarged exteriorly covering about half the club; antepygidial bristle present......* *Hormopsylla* J. & R. (1921) (*fosteri*)

Second segment of antenna not as above; antipygidial bristle absent; seventh abdominal tergite with false comb; all species have five combs (including the prothoracic) but in one (*N. dictenus*), the three middle have only one pair of very short teeth.
Nycteridopsylla Oudemans (1906) (*pentactenus*)

75. Abdomen with five or seven combs.................................76

Abdomen with false combs, also metathorax, composed of the thickened bristles of the submedian row which are placed close to the apical edge of the tergite because of the border being sinuate dorsally.
Myodopsylla J. & R. (1911) (*insignis*)

Abdomen without combs...77

76. Abdomen with seven combs....*Ischnopsyllus* Westwood (1833) (*elongatus*)

Abdomen with five combs..*Hexactenopsylla* Oudemans (1906) (*hexactenus*)

77. Epimerum of metathorax with comb; first abdominal tergite small.
Chiropteropsylla Oudemans (1908) (*aegyptius*)

Epimerum of metathorax without comb...............................78

78. Posterior margin of occiput behind antennal groove, with four or more short, strong, pointed, spine-like bristles; metepimerum higher than long.
Araeopsylla J. & R. (1921) (*scitulus*)

Posterior margin of occiput with only the usual bristles............... ...79

79. Occiput with about six dorsal incrassations, thorax with similar structures, bases of abdominal segments with one such incrassation.
Largaropsylla J. & R. (1921) (*signata*)

Occiput and thorax without incrassations.
Rhinolophopsylla Oudemans (1910) (*unipectinata*)

Synonyms:

Ceratophyllus = *Stenonotus* = *Monopsylla*
Ctenophthalmus = *Spalacopsylla*
Doratopsylla = *Stenopsylla*
Leptopsylla = *Ctenopsylla*
Malacopsylla = *Megapsylla*
Notiopsylla = *Goniopsylla*
Rhopalopsyllus = *Rothschildiella*
Trichopsylla = *Chaetopsylla* = *Oncopsylla*
Xenopsylla = *Loemopsylla*
Echidnophaga = *Argopsylla* = *Xestopsylla*
Hectopsylla = *Rhyncopsylla*
Tunga = *Sarcopsylla* = *Rhynchoprion*

FAMILY TUNGIDAE

Genus Tunga Jarocki (1838)

Description.—Labial palpi pale, consisting of one segment; head not divided by a groove or an internal thickening from the antennal groove upwards; prosternite not produced posteriorly into a distinct conical tooth; hind coxa produced anteriorly at the apex into a tooth, no patch of spines on the inner side; hind femur simple; tibiae with three pairs of dorsal bristles; tarsi very slender, some of the apical bristles on segments 2, 3 and 4 of hind tarsi very long and thin; 5th. segment linear about eight times as long as it is broad with a few long and thin hairs; claws slender without basal projection; female without anal style and without stigma on first, second and third abdominal tergites.

Three species of this genus are known, namely:

Tunga penetrans Linnaeus (1758) with eyes distinct.

Tunga caecata Enderlein (1901) with eyes vestigial.

Tunga caecigena Jordan and Rothschild (1921) with eyes completely absent.

Tunga Penetrans

This is a flea of tropical and subtropical America and has been introduced into Africa. It is known locally as the jigger or chigoe.

The hind legs are not well developed as in other fleas, for part of its life history is spent as a fixed parasite on man and the lower animals. The mandibles are very stout. The female fixes her mouth parts in the skin and the resulting irritation produces a swelling which encompasses the insect except for a small opening at the end of the abdomen. Through this opening she is enabled to secure air and to lay her eggs which drop to the ground and hatch similarly to other fleas' eggs. At the termination of the egg laying period the adult dies. The skin between the toes is oftenest attacked. Infection may follow producing a dermatitis and pustular conditions. The flea is more prevalent when the weather is warm and dry.

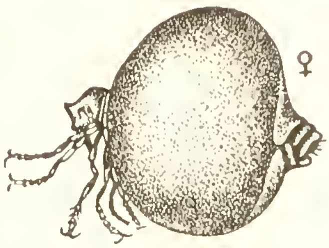

FIG. 58. *Tunga penetrans*, egg-distended female. (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology," 7th Edition.)

Genus Echidnophaga Olliff (1886)

Description.—Labial palpus consisting of one segment; head angulate in front and divided by a groove or an internal thickening from the antennal groove upwards; abdominal segments 2 to 8 with a

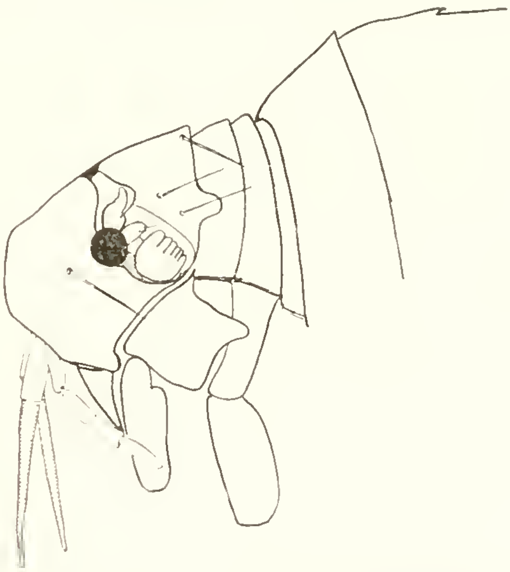

FIG. 59.—Head and thoracic nota of *Echidnophaga gallinacea*.

stigma in both sexes; hind coxa anteriorly produced at the apex into a broad tooth and bearing on the inner side a patch of spinelets; hind femur simple; anal segment of female with style.

There are eight species of this Genus found in Asia, Africa, Europe and Australia. Only one, *E. gallinacea*, has been introduced into America.

Echidnophaga gallinacea Westwood. (Fig. 59)

In this flea the fifth tarsal segment has two ventral apical bristles and there is a small lateral lobe at hind margin of head. It is a flea of chickens and has been taken off other domestic animals and rats. It will attack man.

FAMILY PULICIDAE

Genus Pulex Linnaeus (1758)

Description.—Frontal notch absent; eye present; club of antenna short distinctly segmented only on the posterior side; antennal

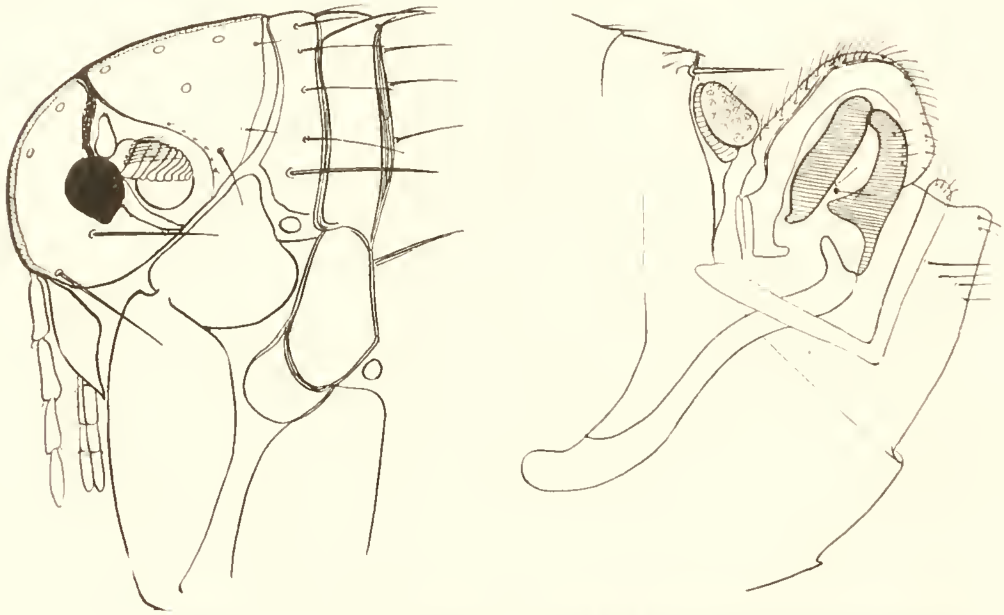

Fig. 60.—Head, prothorax, mesothorax and genitalia of *Pulex irritans* (male).

groove closed behind, the genal process separating the antennal groove from the fore coxa; no spines on gena, at times a small tooth at genal edge of head slightly behind lower oral corner; two bristles on gena, an ocular and an oral; labial palpi of four segments; tip of rostrum asymmetrical; mandibles broad, short and densely serrate; hind coxa with a comb of spinelets on the inner surface anteriorly and a number of hairs posteriorly; fifth tarsal segment with four lateral bristles besides the subapical hair; an antepygidial bristle on each side separate from the apical edge of the 7th. tergite; pronotum without a comb of spines; mesosternite very narrow, without internal rod-like incrassation from the insertion of the coxa upwards, claspers with two movable processes forming a kind of pincers which is cov-

ered by a third process in the shape of a large hairy flap, all processes conspicuous.

Two species of *Pulex* have been described. The common, well known, widely distributed species is *Pulex irritans* the type of the genus. (Fig. 60.) Baker has reported another from Mexico, *Pulex dugesi*. This differs from P. *irritans* mainly in the length of the rostrum, which in *P. irritans* reaches to about half the length of the anterior coxa and in *P. dugesi* to about three fourths the length of that coxa.

Genus Xenopsylla Glinkewicz (1907)

Description.—Frons without a notch or tubercle; eye present; genal process almost completely closing the antennal groove, separating it from the prosternum and being pointed behind; anterior angle of genal edge of head not produced into a triangular lobe; no spines on head; club of antennae short, distinctly segmented only on the posterior side; eye present; two bristles on the gena, one in front of the eye and one near the lower genal border, labial palpi with four segments; tip of rostrum asymmetrical, no spines on prothorax; hind coxa with a comb of small teeth (spinelets) on the inner side; fifth tarsal segment with four lateral bristles besides the subapical hair; an antepygidial bristle on each side separate from the apical edge of the 7th. tergite at times placed on a tubercle; mesosternite with a rod-like incrassation from the insertion of the coxa upwards; claspers with two or three small processes, manubrium narrow, upper internal portion of the 9th. sternite not very sharply defined.

XENOPSYLLA CHEOPIS ROTHSCHILD (FIG. 61)

This is the Indian rat flea and very likely the true plague flea. Cragg has pointed out that in parts of India where this rat flea predominates, epidemics of plague are not uncommon while in those parts of India where other rat fleas predominate epidemics of plague are rare or absent. *X. cheopis* is cosmopolitan in its distribution and is present on the East, South and West coast of the United States. Whether it is present in the interior of the United States is not known. It has been carried from port to port by ship rats most of which are black rats (*Rattus rattus*).

The labial palpi reach to the apex of the fore coxa; the median saggital incrassation of the occiput has an even contour; the episternum and sternum of the metathorax are separated from each

other by a suture; the episternum bears one bristle, the sternum 1, and the epimerum 10 to 17 in two rows (5 to 8, 5 to 7); the mesosternite bears 5 bristles; the hind femur has a tooth ventrally at its widest portion, a row of 5 to 9 bristles on the inner surface and two

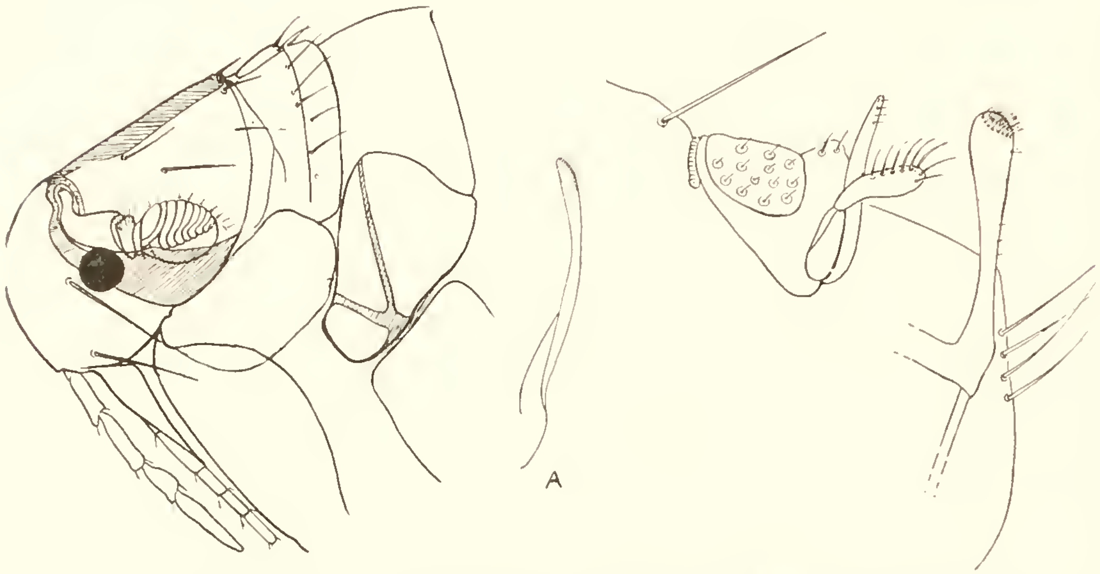

FIG. 61.—Head, prothorax, mesothorax and genitalia of *Xenopsylla cheopis* (male): (A) 9th sternite of *X. astia.*

subapical bristles on the outer surface; the antepygidial bristle is not on a cone like process; the longest apical bristle of the second hind tarsal segment reaches to the middle of the fifth segment; there are two movable processes, to the claspers, one narrow and more or

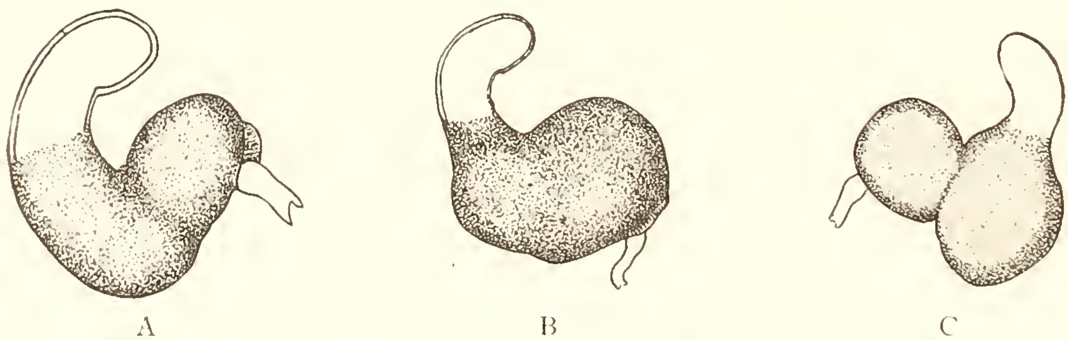

FIG. 62.—Receptaculum seminis of (A) *Xenopsylla cheopis;* (B) *X. brasiliensis;* (C) *X. astia.*

less straight, the other with rounded contour its upper border being more convex than the lower and containing along its edge a number of bristles; the ninth sternite is club shaped gradually but distinctly expanded towards the end; receptaculum seminis as in (Fig. 62A).

Xenopsylla astia Rothschild. This is also a rat flea of India, Ceylon, Philippine Islands etc. It can be distinguished from

X. cheopis by the ribbon-like ninth sternite (Fig. 61A), the "keel" shaped contour of the median sagittal thickening of the occiput in the male and the shape of the receptaculum seminis in the female. (Fig. 62C.)

Xenopsylla brasiliensis Baker is a rat flea of India, Africa and South America. This can be distinguished from the others by the different shape of the receptaculum seminis (Fig. 62B) and by the antepygidial bristle which in the male is carried on a cone.

Genus Ctenocephalus Kolenati (1859)

Description.—Frontal notch absent; eye present; labial palpi four segmented; club of antenna distinctly segmented only on posterior side; two bristles on gena an ocular and an oral; a comb of spines on lower edge of gena; a comb of spines on the prothorax; one antepygidial bristle on each side; minute teeth (spinelets) on inner side of hind coxa; fifth tarsal segment of all legs with four bristles on each side besides a thin and long subapical hair.

CTENOCEPHALUS CANIS CURTIS (FIG. 63)

This is the dog flea. The labial palpi reach to two-thirds of the anterior coxae; there are seven stout pointed spines along the lower

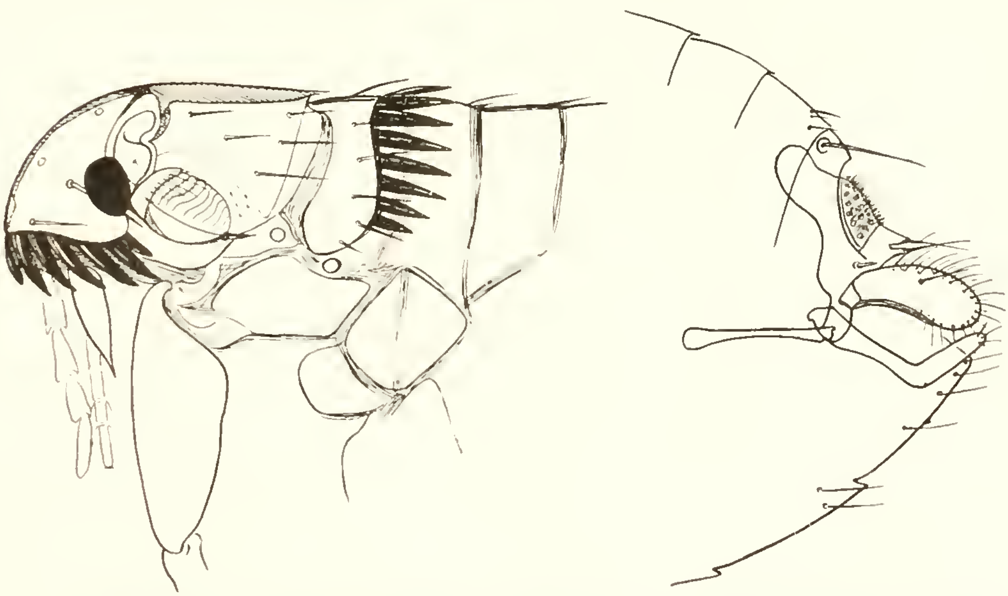

FIG. 63.—Head, prothorax, mesothorax and genitalia of *Ctenocephalus canis* (male).

margin of the gena; the posterior angle of the gena usually ends in a small tooth; there is a ctenidium of from 14 to 16 spines on the prothorax; one of the apical bristles of the second joint of the hind

leg reaches nearly to the middle of the fifth joint; the stigmata are large; the manubrium of the claspers is short and narrow; the movable finger is short, thick, swollen at its middle, bluntly rounded at its distal extremity and contains on its rounded border numerous hairs. *Ct. canis* has been reported as the intermediate host of *Dipylidium caninum, Hymenolepis diminuta, Dirofilaria immitis; Leishmania donovani* and *L. infantum.*

CTENOCEPHALUS FELIS BOUCHÉ

This is the cat flea. The differences between this and the dog flea as pointed out by Rothschild are not marked but constant. They may be studied from the following tabulation. *C. felis* has been reported as intermediate host for *Dipylidium caninum* and *Dirofilaria immitis.*

	Ctenocephalus canis	*Ctenocephalus felis*
First and last genal spine	Shorter in *canis.*	
Head	Shorter and more rounded especially in female.	Longer and more pointed especially in female.
Bristles on hind tibia between fifth and apical dorsal pairs.	Two in number.	A single bristle and a minute hair.
Abdominal stigmata	Larger in *canis.*	
Mid-tarsus		Slenderer in felis.
Eighth tergite of female		More rounded at apex, style more slender than in *canis.*
Bristles on metathoracic episternum	3 or 4.	2 or 3.
Bristles on metathoracic epimerum.	1st. row, 7 to 11. 2nd. row, 7 to 9.	1st. row, 5 to 8. 2nd. row, 5 to 7.
Bristles on inner side of hind femur.	10 to 13.	7 to 10.
Movable finger	The ventral edge is much straightened.	A few more hairs on the surface; the dorsal edge is more rounded and produced further along the ventral edge.
Manubrium	Anterior portion considerably broader than the posterior.	Almost the same breadth along its entire length.

Genus Hoplopsyllus Baker (1905)

Description. Frontal notch absent; eye present; labial palpi with four segments; two bristles on gena an ocular and an oral; no

spines on head; club of antenna segmented only on posterior side; no oblique rows of bristles on occiput, a comb of spines on the prothorax; two antepygidial bristles, one on each side; a row of spinelets on inner side of hind coxa; fifth tarsal segment on all tarsi with four bristles on each side besides a thin and long subapical hair.

It will be noted that the foregoing genera of the Pulicidae, have many points in common but differ in certain outstanding features such as the presence or absence of ctenidia and the type of clasping organs.

HOPLOPSYLLUS ANOMALUS BAKER (FIG. 64)

A flea of the California ground squirrel (*Citellus beecheyi*). The mandibles reach to scarcely half of the anterior coxae; the pronotum has a ctenidium of about 9 spines; the bristles on the second joint

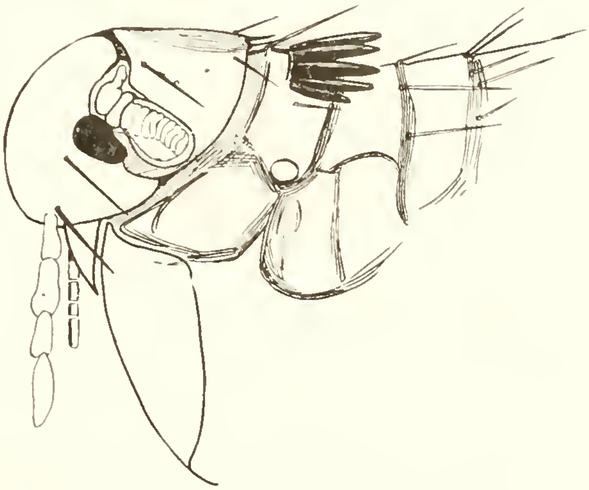

FIG. 64.—Head and prothorax of *Hoplopsyllus anomalus* (male).

of the antenna are considerably longer than the third joint; one of the apical bristles on joint 2 of hind tarsi is longer than joint 3 and 4 together; the lateral portion of the ninth tergite is a large sclerite, rounded above, with a stout tooth at the posterior upper angle and numerous bristles along the upper margin; the movable finger has the shape of an elongated, inverted plowshare with the point directed cephalad and with a few weak hairs on the posterior border.

FAMILY CERATOPHYLLIDAE

Genus Ceratophyllus Curtis

Description.—Frontal tubercle present; eye present occasionally vestigial; head of female evenly rounded, of the male flattened on

top; club of antenna segmented all round; no spines on head; labial palpi five segmented; a comb of spines on the pronotum; three antepygidial bristles on each side in the female, often fewer in the male; pygidium not convex; no spinelets on inner side of hind coxae; fifth joint of all tarsi with five bristles on each side, all in line or only the proximal pair dislocated towards the median line; claspers with one movable process; outline of claspers distinct; inner vertical portion of ninth sternite distinct, external horizontal portion broadened, membranous with a sinus in its posterior border.

CERATOPHYLLUS FASCIATUS BOSC. (FIG. 65)

The European and North American rat flea. The labial palpi reach not quite to the apex of the anterior coxae; there are three

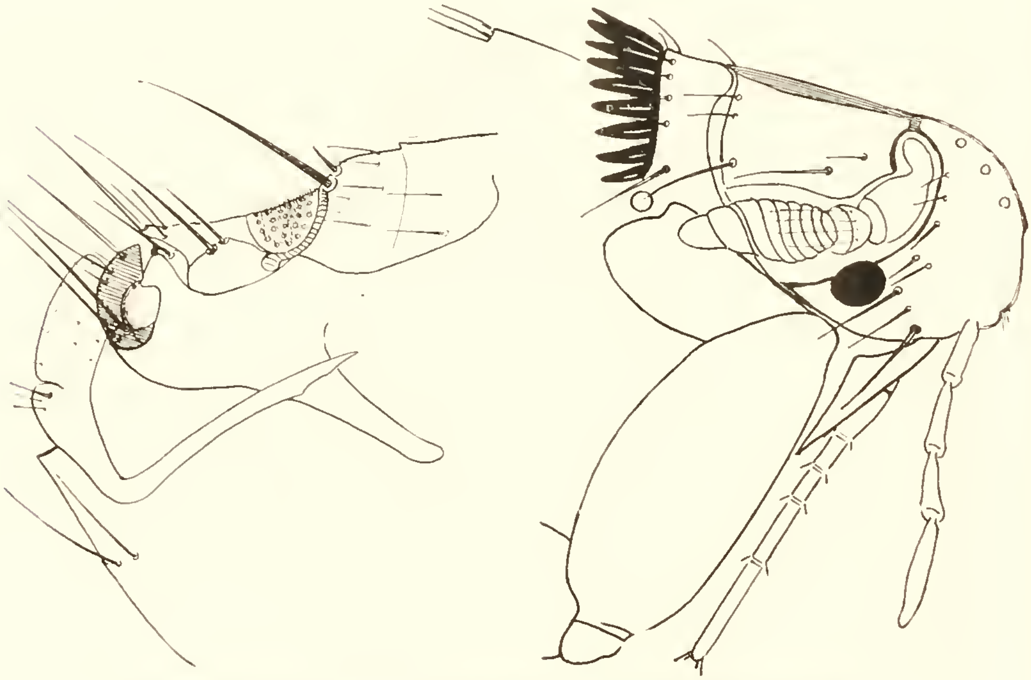

FIG. 65.—Head, prothorax and genitalia of *Ceratophyllus fasciatus* (male).

bristles in the lower genal row, evenly spaced; the upper row is represented by three small bristles along the edge of the antennal groove, the lowermost frequently paired in the male; the second joint of antenna contains about five hairs about as long as third joint; there are about 18 spines in the pronotal ctenidium; there are two rows of bristles on the abdominal sternites, a posterior of about 12 or 14 and an anterior of smaller less numerous bristles; on the inner

side of the hind femur is a row of 3 or 4 bristles; on outer side of hind tibiae there are 8 to 12 lateral bristles; none of the bristles at the apex of the hind tibia is longer than the next succeeding joint; the lateral bristles on the fifth tarsal joints of all legs are in a uniform row; the finger of the claspers is short extending to a little beyond the immovable process, its distal edge is convex, its proximal edge angulate, from the distal edge there are two large and two small bristles alternating; the ninth sternite is broad and thin with a deep sinus in its posterior border and its surface containing numerous hairs; in the female the sternite of the seventh abdominal segment is never distinctly sinuate; receptaculum seminis as in (Fig. 68F).

CERATOPHYLLUS ACUTUS BAKER (FIG. 66)

This is a flea of the California ground squirrel. There are three bristles in the lower genal row the middle bristle close to the upper;

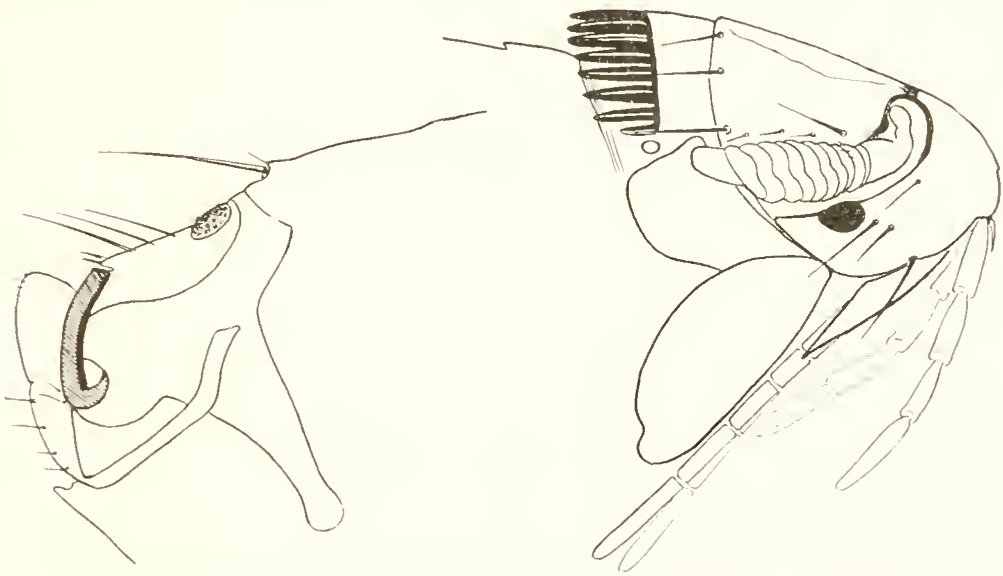

FIG. 66.—Head, prothorax and genitalia of *Ceratophyllus acutus* (male).

the upper genal row is represented by one or two small bristles at the edge of the antennal groove; the labial palpi are long extending well beyond the trochanters; the longest bristle on the second joint of hind leg extends to the middle of the fifth joint; the hind femur has a row of 4 or 5 small bristles on the inner side; the bristles on the margins of the fifth tarsal joint are in a uniform row; the finger of the claspers is very long and slender. It is shaped like the blade of a scythe and extends well beyond the tip of the immovable process; receptaculum seminis as in Fig. 68E.

FAMILY LEPTOPSYLLIDAE

Genus Leptopsylla Jordan and Rothschild (1911)

Description.—The head is subangulate in front; eyes absent; club of antenna segmented all round; a comb of spines on posterior border of gena; oblique rows of bristles on occiput; a comb of spines on the prothorax; bristles on posterior border of tibiae mostly single and in a close set row forming a kind of comb; inner side of kind coxae without spinelets; the last tarsal joint on all legs has on each side four birstles with a proximal pair situated between the first lateral pair.

LEPTOPSYLLA MUSCULI DUGES (FIG. 67)

This is the mouse flea and a flea of rats. It can be readily identified by the four genal spines together with the two short thick spine-

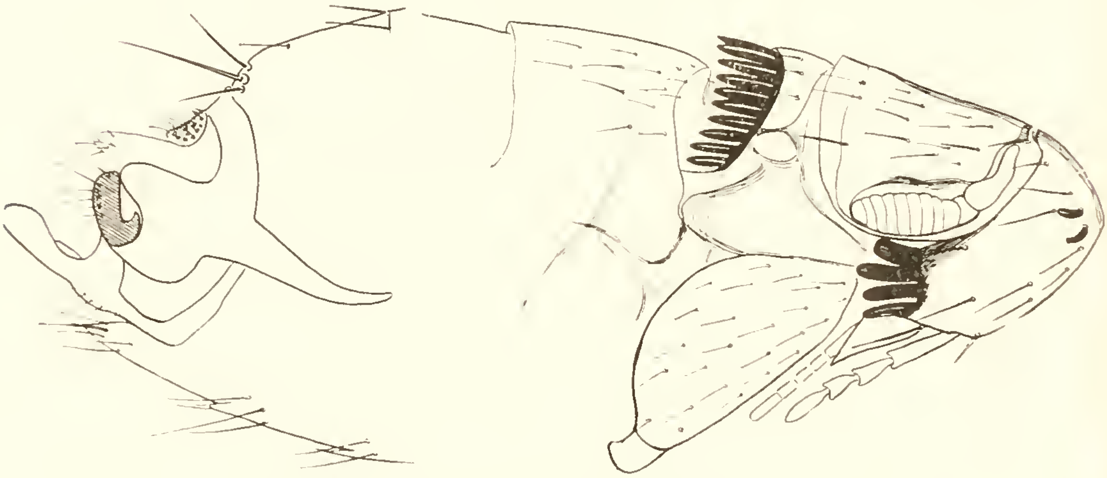

FIG. 67.—Head, prothorax and genitalia of *Leptopsylla musculi* (male).

like bristles anteriorly at the most prominent part of the frons which are characteristic of the genus; receptaculum seminis as in (Fig. 68A).

Eradication

Eggs, larvae and adults may be removed from rugs, carpets etc. by the vacuum cleaner. The dust should be burned.

Dogs may be bathed in a 3% solution of creolin or liquor cresolis compositus or in an emulsion consisting of equal parts of kerosene and a 3% solution of the above. These insecticides should be permitted to act for not less than five minutes and followed by a bath in soap and water. Washing should begin at

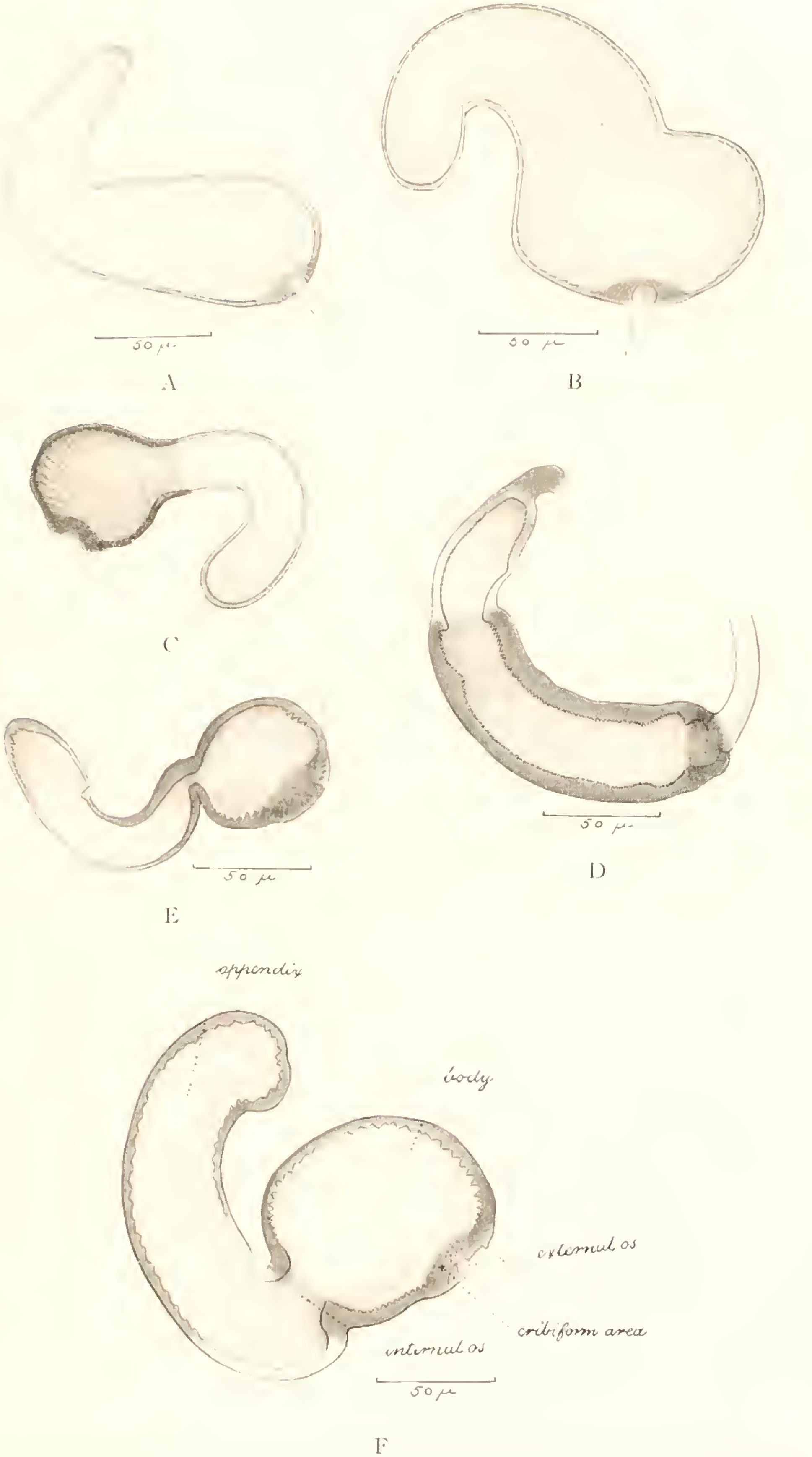

FIG. 68.—Receptaculum seminis of (A) *Leptopsylla musculi*; (B) *Echidnophaga gallinacea*; (C) *Pulex irritans*; (D) *Ceratophyllus niger*; (E) *Ceratophyllus acutus*; (F) *Ceratophyllus fasciatus*.

the head. Cats which are prone to lick themselves after such a bath may be made sick so that it is perhaps better to dust well with pyrethrum powder, first placing the animal on a large piece of paper. The fleas will be stupified and will drop off. The paper with its contents should then be burned.

The animal's bedding should be burned weekly or soaked in 5% cresol solution.

When practicable floors should be mopped with kerosene paying particular attention to cracks, base boards etc. or sprinkled with napthalene. Cellar floors may be white washed.

Ground which has been exposed after a search for rat breeding and harboring places should be soaked with a 5% solution of cresol or one of the cresol preparations.

Fumigation with sulphur, three pounds to 1000 cubic feet, may be practiced. The inclosure to be fumigated should be tightly closed and exposed to the gas for 6 hours. It must be kept in mind that sulphur may tarnish metals and may be destructive to fabrics, paintings, etc.

Cyanide fumigation is efficatious but dangerous and should be used only by one thoroughly trained in the procedure.

CHAPTER XVII

ORDER ANOPLURA

(Lice)

The term lice is commonly applied to two different groups of wingless insects which resemble each other more or less closely but are never-the-less distinct. One group (the biting lice) called the Mallophaga is comprised of the lice which are more especially found on birds and which have masticatory mouth parts and feed on epidermal scales and feathers. They do not attack man and are therefore of little interest from the standpoint of preventive medicine. The other group (the sucking lice) is called the Anoplura and is comprised of those lice having suctorial mouth parts and which dwell upon warm blooded animals including man and subsist upon blood. These are the lice of special interest in preventive medicine.

The Anoplura are degenerate parasitic insects. They lack wings. They are flattened dorso-ventrally. Their mouth parts are adapted to piercing the skin and sucking blood and are retracted inside the head when not in use. The metamorphosis is incomplete in that the young and adults have a similar form and eat the same food and there is no pupal or quiescent stage in the life history. Three moultings occur before the adult stage is reached and the sexual organs are distinct.

Adult.—Anatomy.—Like all insects the body is divided into a head, thorax and abdomen. There may be two small but distinct *simple eyes* or *ocelli*, one situated on each side of the head at its broadest part. In front of these, one on each side, is a three to five jointed *antenna*. At the most anterior part of the head is located the mouth opening which is surrounded by a ring of tissue, the *haustellum*, bearing a number of *hooklets* (*prestomal teeth*). At rest the piercing organs are withdrawn into the head by an invagination of the integument. The *stylet* is composed of three parts. These when protruded from the head and apposed form a tube through which the blood is drawn up by the action of the aspiratory muscles. In the act of biting the haustellum is placed against the

skin where it is held firmly by the hooklets, forming an air tight ring. The stylet or stabber is then inserted, the saliva injected and the blood withdrawn. During the operation which may last more than 30 minutes, the blood may be seen to pass into the digestive system and the waves of contraction of the aspiratory apparatus and of the alimentary canal may be observed. As in other degenerate parasites the ejection of feces often accompanies feeding. The body louse usually clings to fibres of the clothing while feeding. Feeding normally takes place 4 or 6 times a day and most of the biting is done where the clothing is tightest (around the neck, waist, back etc.). The blood first passes into the *buccal cavity*, then into the *pharynx* and then backward into the *oesophagus* and *stomach*. The lateral thickenings of the buccal cavity are known as the *fulturae*. The *stomach* is provided with two *lobes* or pockets anteriorly lying on either side of the oesophagus. From the stomach the digested food passes into the *intestine* or *hind gut* at the beginning of which empty four *Malpighian tubules*. There are two pairs of *salivary glands*, one pair (trouser-shaped)lying on either side of the stomach, and one pair (kidney-shaped) lying on either side of the oesophagus between the anterior lobes of the stomach.

The thorax does not show complete segmentation. A *sternal plate* may be observed. It is located in the middle of the ventral surface.

The abdomen is made up of nine segments but the number may be reduced in some species. The tergites and sternites are usually only thinly chitinized but laterally the pleurae may be densely chitinized forming the *pleural plates*. The ninth segment in the female is notched behind forming two flaps, the *telson*. On the ventral surface of the eighth segment are two triangular plates bristled on their edges and known as *gonopods*. These are used to grasp a hair while oviposition is taking place, holding it firmly as the egg is being cemented to it. The ninth segment in the male is rounded, not notched. At the posterior end of the male abdomen may be seen a pointed chitinous organ, composed of two parts, used to dilate and hold open the genital opening of the female allowing the insertion of the penis during the act of copulation.

Breathing occurs through *spiracles* located on each side of the mesothorax and of the third to eighth abdominal segments. The legs are robust and adapted to clinging. They are made up of five joints; a *coxa*, *trochanter*, *femur*, *tibia* (often provided distally with a

thumb-like process) and a *tarsus* terminating in a large movable *claw* which when apposed to the thumb-shaped process of the tibia permits the louse to grasp a hair or fibre of clothing. In some species there is a small plate between the tibia and tarsus known as the *pretarsal sclerite*.

Eggs of the louse are elongate-ovoid with a granulated cap known as the *operculum*. The young lice resemble the adults except for their small size and absence of genital organs.

FAMILY PEDICULIDAE

The lice which infest man belong to the Family Pediculidae, subfamily Pediculinae. The Pediculinae have five-jointed antennae;

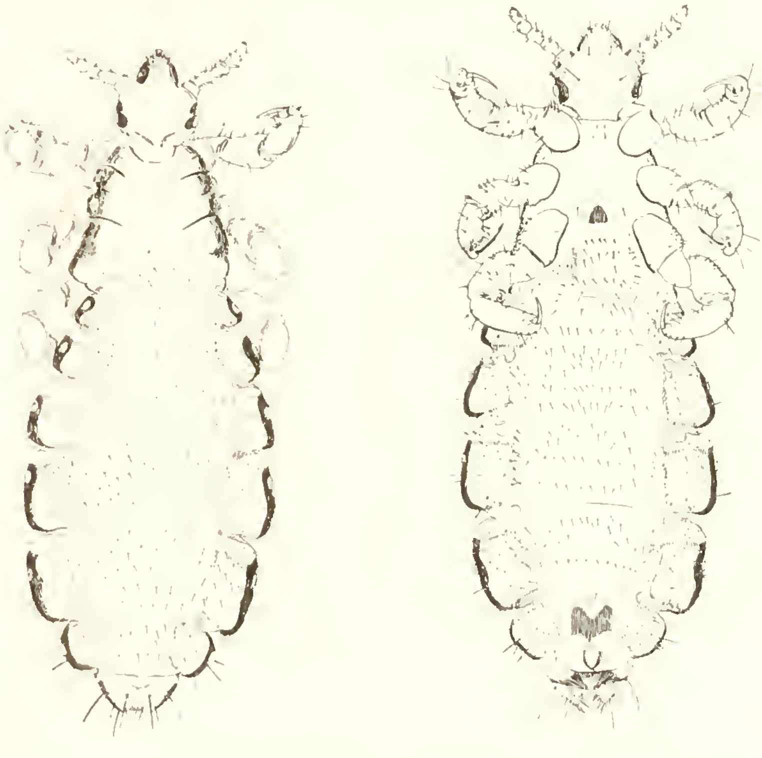

FIG. 69.—*Pediculus humanus*, dorsal and ventral view (female).

there is but one pair of spiracles on the thorax; there is no tubular prolongation in front of the head; the eyes are simple, black and prominent; the thumb-shaped process on the hind tibia is present; the legs are suitable for clinging and the tibiae and tarsi are stout. There are three members of this subfamily, *Pediculus humanus* Linn. 1758 (= capitis) or head louse (Fig. 69). *Pediculus corporis* de Geer 1778 (= vestimenti) (Fig. 70) or body louse and *Phthirus pubis* Linn. 1758 or crab louse. (Fig. 71.)

Anatomical differences between the head and body louse are very slight. They differ in habit or location but very little in structure. The head louse is smaller than the body louse and the lateral constrictions between the abdominal segments are shallower. They will interbreed readily and it is believed by some observers that it would probably be more exact to regard them as varieties of the same species, i.e. *Pediculus humanus* variety *humanus* and *Pediculus humanus* variety *corporis*. On the other hand crab lice are readily distinguished by their different shape.

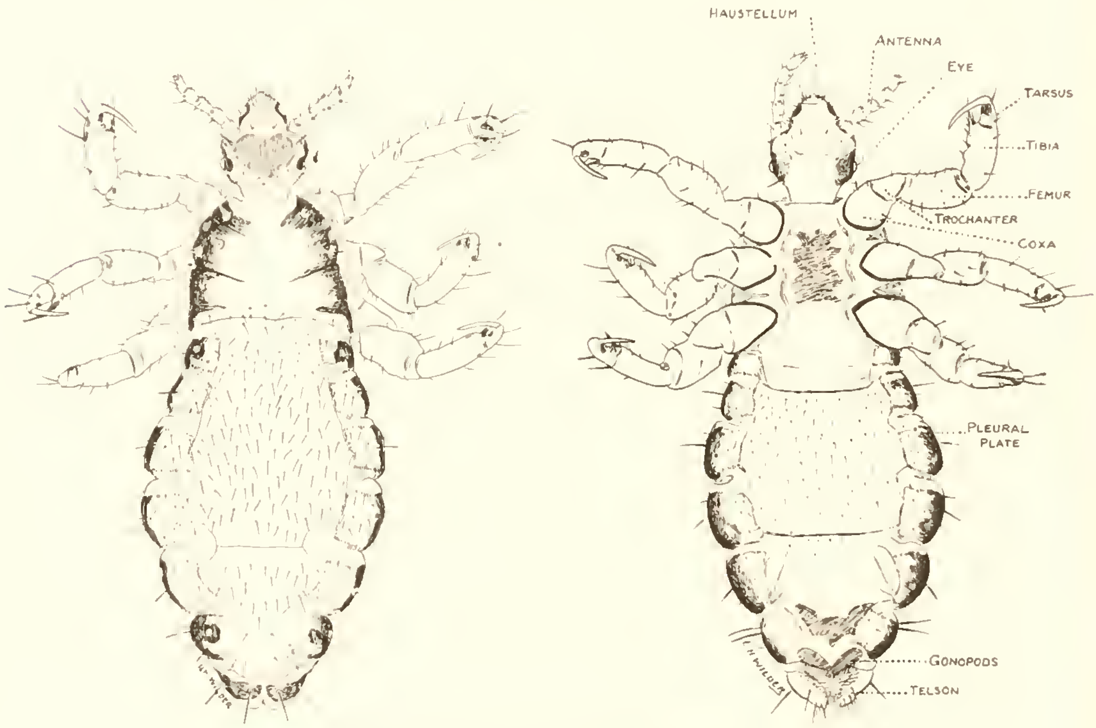

FIG. 70.—*Pediculus corporis*, dorsal and ventral view (female).

Habits.—The head louse inhabits the hairs of the head attaching its eggs with the operculum uppermost near the base of the hairs by means of a cement which is formed in a special gland. As the hair grows the nits are carried farther and farther away from the scalp. Around the ears and the occipital region are favorite locations for oviposition. Children are more likely to be infested and especially girls with their long hair: also old people.

The body louse inhabits the clothing especially at the seams, at arm pits and fork of trousers, attaching its eggs to the fibres of the cloth. Woolen clothing is particularly liable to become lousy on account of the wool fibres to which the eggs may be easily attached.

Cotton and silk are much less likely to harbor lice. There is also a tendency to change woolen clothing, which is mostly worn in winter, less frequently than cotton or silk. Occasionally eggs of the body louse may be found attached to the hairs of the body.

The crab louse inhabits the hairs of the pubic region but at times in badly infested individuals it may extend to the hairs of the body and even to the beard and eyebrows.

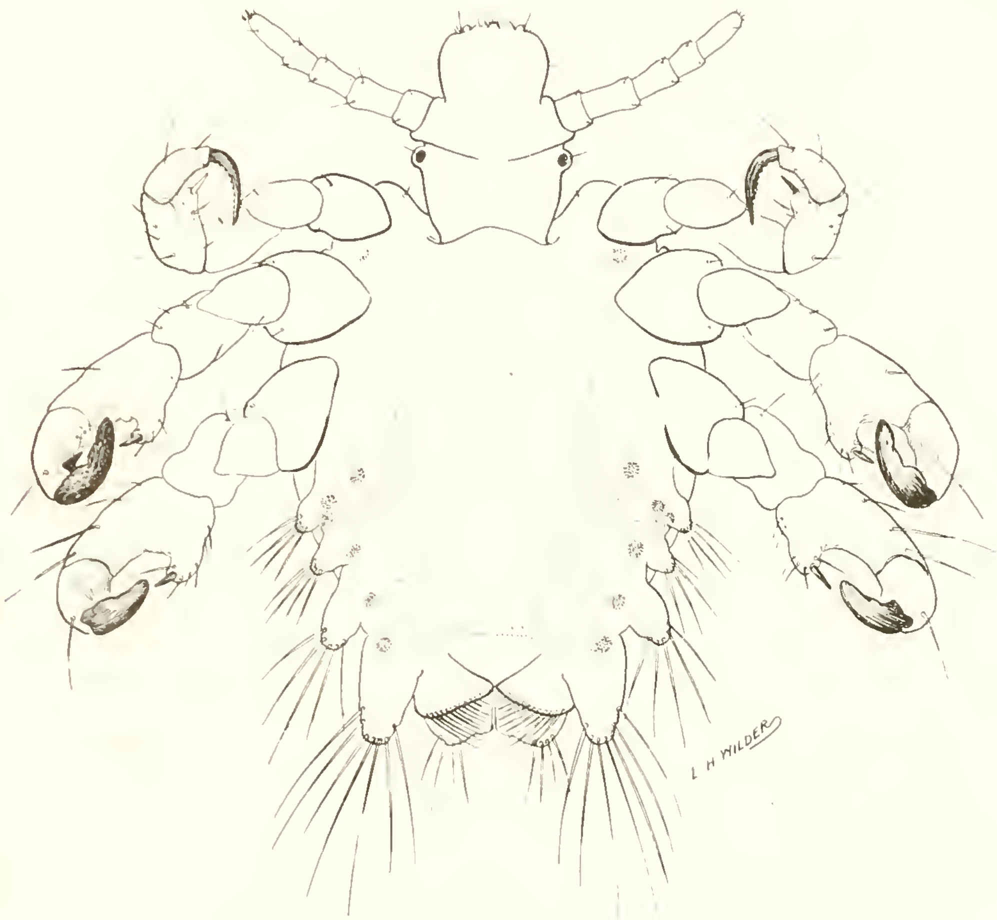

FIG. 71.—*Phthirus pubis*, ventral view, female.

Pediculus corporis

Man and his clothing are the chief disseminators of body lice and only occasionally will they be found in blankets and mattresses and practically never in rooms, beds, trenches etc. apart from their normal host. However the temperature of the surroundings has a marked influence on their movements and vitality so that when the temperature of the environment approximates that of the body, as while in bed, lice will very likely wander from one person to another

or when the skin becomes hot as in a fever, lice show a tendency to leave the body and migrate more rapidly to another. They also leave the body at the death of the host. They are very sensitive to heat and are best adapted to a temperature of between 86 and 90 degrees F., the temperature which exists between the skin and clothing. At 104 degrees they are very active. At 98 degrees they are active and without food die on about the second day. At 60 to 65 degrees F. their activity is not marked and even without food they may live 4 or 5 days. At still lower temperatures they become moribund and die slowly. If, after a delousing process, there is complete absence of peristaltic action in the lice examined, it may be assumed that they are actually dead and will not revive.

In general it may be said that the average life of a louse (body) after reaching maturity is 34 to 40 days. Away from the human body and unfed they die in 3 or 4 days, at most 7 days. The female louse reaches maturity in about 12 days and oviposition begins the second day after the last moult.

Eggs.—Eight to ten eggs a day are laid for about 30 days. They are cemented to the fibres of the clothing, the operculum pointing upward. Under favorable humidity conditions eggs will hatch in 8 or 9 days when kept at a temperature of 87 degrees F. Such conditions exist between the skin and the clothing when constantly worn. At 98 degrees they will hatch in 5 days. Below 72 degrees F. none will hatch. Eggs may hatch as long as 35 days after laying if kept cold, so it is possible for eggs to lie dormant in discarded clothing up to 35 days and still hatch. A fertile egg may be told by observing the reddish or brownish eye spot in the embryo.

When fully developed the nymph emerges from the egg shell by first forcing open the lid or operculum. This permits only a partial escape and to complete the process the larva swallows air which is then emitted from the rectum into the lower part of the shell so that gradually a pressure is obtained sufficient to force the insect completely out of the covering.

Nymphs.—The young look very much like adults except for their smaller size. If not fed they die in 24 to 48 hours. If fed they moult in from 4 to 6 days to enter the 2nd. nymphal stage.

The 2nd. nymphal stage moults in about four days (or 8 days after emergence from the egg) to enter the 3rd. nymphal stage which in another four days (or 12 days after emergence from the egg) moults to become the fully formed adult.

Pediculus humanus

The life history of *Pediculus humanus* is similar except perhaps that the number of eggs laid is fewer and the life of the insect shorter.

Phthirus pubis

Phthirus pubis (Fig. 71) is about as long as broad while the body and head louse are each about three times as long as broad. In the pubic louse the first pair of legs is slender. In the others the first pair of legs is relatively stout and terminate in strong claws markedly serrated on the inner edges. The head is larger than in the other species and there is less demarcation between the thorax and abdomen. Three protuberances bearing hairs may be seen on each side of the abdomen, and the insect is more hairy than the other species. The crab louse usually infests the pubic hairs but may be found on other hairy parts including the hairs of the legs and body, the beard and eyebrows and rarely the head. The eggs of the crab louse can be differentiated from the eggs of the head and body louse by the different appearance of the cap or operculum which in the crab louse is more conical with larger more prominent nodules. Eggs hatch in from 6 to 8 days. Three moultings over a span of 14 days are required to reach maturity after which the adult lays about two eggs a day for another 14 days when it dies. Crab lice are very persistent feeders and adhere closely to the skin. They are spread from person to person during coitus and by means of the eggs attached to hairs shed in toilets or by the use of clothing which has been worn by others.

Diseases Transmitted by Lice.—It is known that the body louse is the carrier of typhus fever (see Chapter XXXIII), trench fever (see Chapter XXXIV) and European relapsing fever (see Chapter XXXV). Urticaria and melanodermia (vagabond's disease) may follow from the irritation of the bite and cutaneous pyogenic conditions from the scratching. The head louse may carry typhus fever and it is said that this louse may also carry favus and impetigo. The pubic louse so far as known, is not responsible for the spread of any disease, although it is certainly a potential carrier and great irritation of the skin under the pubic hairs may follow its bite.

CLASSIFICATION

Many lice besides those infesting human beings are known to science. Each has for its host a particular species of warm blooded

animal and it is not common to find one on an animal other than its normal host and then usually on a closely related species. Neither do lice survive for any length of time away from a host. Just why they are so dependent upon one species of animal is not known. It may be body temperature, serum reaction, thickness of skin or the size of the hairs to which they cling. Certainly they are very susceptible to temperature and humidity conditions. These remarks are equally true of the biting lice, the Mallophaga.

Monkeys.—The lice of monkeys and apes belong to the Family Pediculidae. In fact the louse of apes is in the Subfamily, Pediculinae, but can be told from the man-infesting species of *Pediculus* in that some of its pleural plates have lateral lobes. Most of the lice of monkeys belong to the Subfamily Pedicininae, the members of which have three-jointed antennae.

The Dog (*Canis familiaris*).—The sucking louse of the dog is *Linognathus piliferus* Burmeister. It is not often encountered.

The genus *Linognathus* is characterized by having five-jointed antennae; the middle and posterior pairs of legs are nearly equal in size and larger and stouter than the anterior pair; the abdomen is without chitinized tergal, sternal, and pleural plates; each abdominal segment has two or three rows of rather long hairs; eyes are absent; the head is rather slender and the thorax small and elongated.

Two species of biting lice have been recorded from dog, *Heterodoxus longitarsus* and *Trichodectes latus*. The former is a kangaroo louse on the dog only by accident. The latter is found with more or less frequency.

The Domesticated Cat (*Felis domesticus*).—The cat has no sucking louse. The Mallophagan louse of the cat is *Trichodectes subrostrata*. This has also been recorded from the wild cat.

The Horse (*Equus caballus*).—The sucking louse of the horse is *Haematopinus asini* Linne which is also reported from the donkey.

In the genus *Haematopinus* the head is very broad posteriorly with the temporal angles very prominent; the antennae are five-jointed; the thorax is broad and the sternal plate well defined; the legs are nearly all of the same size; pretarsal sclerite is present; pleural plates are strongly developed from third to eighth segment; there is but one row of bristles on each abdominal segment; the tergites have many small chitinized plates but these plates may be absent.

The biting lice of the horse are *Trichodectes equi* and *T. pilosus*. The latter has not been reported from the United States.

The Domesticated Hog (*Sus scrofa domestica*).—The sucking louse of the hog is *Haematopinus suis* Linne (= *urius* Nitzsch) which passes temporarily to man. No biting lice have been recorded from hogs.

The Domesticated Cow (*Bos taurus*).—The sucking lice of cattle are, *Haematopinus eurysternus* Nitzsch, the "short nosed ox louse," *Linognathus vituli* Linne "the long nosed ox louse" and *Solenopotes capillatus*. The biting louse is *Trichodectes scalaris*.

Domesticated Sheep (*Ovis aries*).—The sucking louse of sheep is *Linognathus pedalis* Osborn. It occurs on the legs and feet below the long wool. It is not common. Biting lice have not been recorded from sheep.

The Domesticated Goat (*Capra hircus*). The sucking louse of the goat is *Linognathus stenopis* Burmeister. Two different biting lice have been taken from the Angora goat, *Trichodectes climax* and *T. hermsi*. The latter is much larger than *T. climax* and has on its head and abdomen numerous short, spiny hairs irregularly disposed.

The Rabbit.—The common sucking louse of the rabbit in the United States is *Haemodipsus ventricosus* Denny. It may be taken from wild or tame rabbits.

The genus *Haemodipsus* is characterized by having a short head, broader posteriorly; the abdomen is without chitinous plates or else the pleural plates are extremely small; the abdominal segments have a single row of rather closely spaced very long hairs; the anterior legs are more slender and smaller than the others; eyes are absent; antennae are five-jointed.

In *H. ventricosus* the thorax is narrow and the sternal plate hexagonal all of its margins being nearly equal in size; pleural plates are present on the third to sixth segments but they are very small and tooth-like with the base attached to the body and the point free.

The Domesticated Guinea Pig (*Cavia cobaya*).—Sucking lice have not been recorded from this animal. Two forms of biting lice are common, *Gliricola porcelli* and *Gyropus ovalis*. The latter can be readily distinguished from the former by its very broad abdomen, almost twice as broad as long.

Domestic Rats.—*Polyplax spinulosa* Burmeister is the common sucking louse of the rat. (Fig. 72.) At times *P. serratus*, a mouse louse, may also be encountered. Two other forms also have been taken off rats, *P. miacanthus* and *Hoplopleura acanthopus* which

probably has as its normal host, a field mouse (*Microtus*). In the United States *H. acanthopus* is represented by a variety, *americanus*.

In the genus *Hoplopleura*, the antennae have five joints, similar in male and female; the first pair of legs is small with slender claws, the second pair larger with broader claws, the third pair very large and stout with very broad, blunt claws; on the hind tibia there is usually

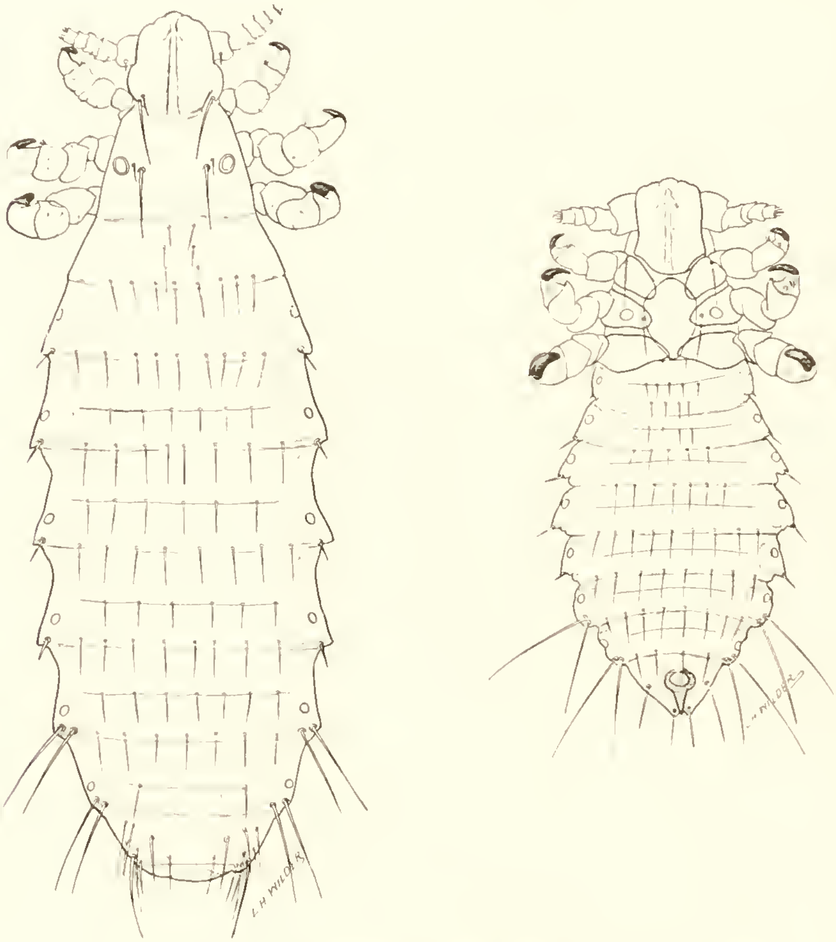

FIG. 72.—*Polyplax spinulosa.* (Left) female; (right) male.

a short, pointed process on the anterior margin; pleural plates are present on the first to eighth segments, they are well developed, large, overlapping, with the posterior margin variously toothed; tergites and sternites of abdomen well chitinized, in the female, tergites four to seven and sternites three to six are transversely divided into three distinct plates, the remaining segments with either one or two plates, each plate having a transverse row of spines; the males have a smaller number of plates; in both sexes the

anterior sclerite of the third sternite has 4 or 6 very long conspicuous spines.

The genus *Polyplax* is characterized by having five-jointed antennae and no eyes; the anterior pair of legs is small, the middle and posterior pairs large; tergites and sternites of the abdomen are well chitinized and some at least are divided transversely into two distinct plates, with one row of hairs on each plate (two rows to each abdominal segment); pleural plates are present on the first to the eighth segments; in the male the 3rd. joint of the antenna usually has a projection apically.

California Ground Squirrel (*Citellus beecheyi*).—The common sucking louse of this squirrel is *Linognathoides montanus* Osborn (= *columbianus*). This species may also be found on other squirrels.

The genus *Linognathoides* resembles *Polyplax* except that there are no defined well chitinized tergal and sternal plates and the third segment of the antenna of the male has no process.

Another species of sucking louse has also been taken off *Citellus beecheyi* namely *Enderleinellus osborni* Kellogg and Ferris.

In the genus *Enderleinellus* the antennae are five-segmented; the posterior pair of legs is large and heavy with a stout claw, the anterior and middle pairs are much smaller and each has a slender, pointed claw; the abdomen is without chitinized tergal and sternal plates or with these plates weakly developed; pleural plates are present on the second to fifth or sixth segments; most of the abdominal segments have one row of hairs; on the third abdominal segment is a pair of widely separated chitinous plates. Another member of this genus, *Enderleinellus suturalis* Osborn, has also been found on a ground squirrel. Both of these species have a transverse suture running across the head just behind the antennae. In *suturalis* the abdominal segments 2 to 7 each have a transverse row of from 18 to 24 long, slender, bluntly pointed hairs arranged in three groups; in *osborni* the abdominal hairs are much fewer and much shorter and stouter.

Key to the Families, Subfamilies and Genera of the Anoplura (Adapted from Kellogg and Ferris)*

1. Body with spines or hairs in definite rows, never with scales; occurring exclusively on land mammals. 5

* The anoplura and mallophaga of North American Mammals. Published by Stanford University, California, 1915.

Body with short stout spines or with spines and scales; occurring exclusively on marine mammals (seals, sea-lions and walruses)
Family Echinopthiriidae..2

2. Antennae five-segmented, thorax and abdomen bearing scales.
Genus *Antarctophthirus* Endeirlen (*ogmorhini*)*

Antennae four-segmented..3

3. Thorax and abdomen bearing scales.
Genus *Lepidophthirus* Enderlein (*macrorhini*)

Thorax and abdomen without scales..................................4

4. Head thorax and abdomen beset with long, heavy spines.
Genus *Echinophthirus* Giebel (*phocae*)

Body clothed with long hairs and short spines, first pair of legs greatly reduced, without tibial thumb and in no way adapted to clasping.
Genus *Procchinophthirus* Ewing (*fluctus*)

5. Head much elongated (tubularly produced anteriorly), cylindrical in shape; tibiae without a thumb-like process opposing the claw.
Family Haematomyzidae

(Containing but one genus, *Haematomyzus*, occurring exclusively on elephants) (*elephantis*)

Head not elongated; tibiae with a thumb-like process opposing the claw.....6

6. Eyes extremely rudimentary or entirely lacking
Family Haematopinidae..11

Eyes present, usually well pigmented (Page 145).....Family Pediculidae..7

7. Antennae distinctly five-segmented (Page 145)...Subfamily Pediculinae..9

Antennae distinctly three-segmented or indistinctly five-segmented (on monkeys)..................................Subfamily Pedicininae..8

8. Legs all of same size................Genus *Pedicinus* Gervais (*eurygaster*)

Middle and posterior legs larger and stouter than anterior.
Genus *Phthirpedicinus* Fahr. (*micropilosis*)

9. Legs all of same size (Page 145)..........Genus *Pediculus* Linn. (*capitis*)

Anterior legs smaller than the others..................................10

10. Abdomen long, segments two, three and four distinct each bearing a pair of spiracles in the normal lateral position.
Genus *Phthirpediculus* Ewing (*propitheci*)

Abdomen greatly shortened, segments two, three and four strongly compressed so that the spiracles are crowded together and appear to be in one segment (Page 149)....................Genus *Phthirus* Leach (*pubis*)

11. Antennae five-segmented..13

Antennae three-segmented.............Subfamily Euhaematopininae..12

12. Posterior legs with stalked, disk-shaped appendages on femur and tibia.
Genus *Euhaematopinus* Osborn (*abnormis*)

Posterior legs without appendages.
Genus *Haematopinoides* Osborn (*squamosus*)

13. Anterior legs smaller and with slenderer claws than posterior at least.
Subfamily Linognathinae..14

Legs and claws all of same size (Page 150).
Subfamily Haematopininae (One genus *Haematopinus* Leach (*suis*))

* The specific name in parenthesis is the type of the genus.

14. Anterior tarsi with two joints Genus *Hypophthirus* End. (*notophallus*)
Anterior tarsi with but one joint. 15
15. Anterior pair of legs with two claws. . . Genus *Scipio* Cummings (*aulacodi*)
Anterior pair of legs with but one claw. 16
16. Abdomen with well developed pleural plates 20
Abdomen entirely without pleural plates. 17
17. Abdominal spiracles large, tubular, projecting from the body wall.
Genus *Solenopotes*
Abdominal spiracles small, not projecting from body wall. 18
18. Gonopods of female long or moderately long. 19
Gonopods very short; head broad, considerably widened behind the antennae; infesting rabbits; abdomen with but one row of hairs or spines on each segment (Page 151).
One species of the Genus *Haemodipsus* End (*lyriocephalus*) (in part)
19. Gonopods long, frequently reaching beyond the extremity of the body; head usually slender, but little widened behind the antennae; abdomen with more than one row of hairs or spines on each segment; for the most part infesting Ungulates (Page 150).
Genus *Linognathus* Enderlein (*piliferus*)
Gonopods moderately long, behind each gonopod a stout, flat, spine-like process, abdomen with but one row of hairs or spines on each segment.
Genus *Cervophthirus* Mjoberg (*tarsandi*)
20. Tergites and sternites of the abdomen for the most part with more than one transverse row of hairs or bristles. 25
Tergites and sternites of the abdomen for the most part with but one row of hairs or bristles. 21
21. Leg I smaller than either II or III and with smaller and more slender claw. 23
Anterior and middle pairs of legs of the same size or subequal, smaller than the posterior pair which are large and stout. 22
22. Pairs of pleural plates five or less (Page 153).
Genus *Enderleinellus* Fahr. (*sphaerocephalus*)
Pairs of pleural plates seven. . . . Genus *Proenderleinellus* Ewing (*africana*)
23. Abdomen with a pair of chitinized plates on the second or third sternite.
Genus Fahrenholzia Kell. & Fer. (*pinnata*)
Abdomen without such plates. 24
24. Occiput deeply sunk into the thorax; rostrum surrounded by denticles; pleural plates quite large. . . Genus *Eulinognathus* Cummings (*denticulatus*)
Occiput not deeply sunk into the thorax; rostrum not surrounded by denticles; pleural plates minute. . . . . . Genus *Haemodipsus* (in part)
25. Abdominal tergites and sternites with not more than two rows of hairs or bristles. 27
Abdominal tergites and sternites in part with three rows of hairs or bristles. . 26
26. Pleural plates with posterior margin variously toothed, second pair of plates of same type as others (Page 152).
Genus *Hoplopleura* Enderlein (*acanthopus*)
Second pair of pleural plates enormous and wing-like.
Genus *Pterophthirus* Ewing (*alata*)

27. First antennal joint with a stout spine at the distal post-axial angle or on the posterior margin..........Genus *Neohaematopinus* Mjoberg (*sciuropteri*)
First antennal joint not so..28
28. Abdominal tergites and sternites with distinct chitinized tergal and sternal plates (Page 153)................Genus *Polyplax* End. (*spinulosa*)
Abdominal tergites and sternites without distinct chitinized plates in the female and with these absent or extremely reduced in the male (Page 153).
Genus *Linognathoides* Cummings (*citelli*)

Eradication

Nits and lice are destroyed within thirty minutes by hot water or dry heat at 55 degrees C., even when protected by a covering of khaki cloth. If the temperature is raised to 60 degrees C. 15 minutes will suffice. If, during the process of washing or drying garments, they are subjected to the temperatures and periods given above, chemical solutions are unnecessary. The evidence seems to establish the fact that steeping for 20 minutes in a 2% watery solution of equal parts of crude carbolic acid and soft soap (lysol) is effective provided the temperature of the solution is not below 50 degrees F. (Bacot and Lloyd).

Both lice and nits can be destroyed by the immersion of verminous garments in gasoline, benzine, kerosense, turpentine, dichlorethylene, or tetrachlorethane. The latter two are non-inflammable. Danger from fire when gasolene or benzine is used may be avoided by the use of a bath and extractor as employed in "dry cleaning."

Fabrics such as bed clothes, underclothing, and outer garments may be baked, boiled or steamed. Both lice and nits are killed by dry heating to 70 degrees C. (158 degrees F.) for 10 minutes. Dry heat at 100 degrees C. (212 degrees F.) will kill nits and lice in about one minute, while boiling water requires but 30 seconds. Care must be exercised to make sure that the desired temperature has actually penetrated to the center of the material to be disinfested. Dry heat does not penetrate readily.

Where a double jacketed steam chamber is available, it should be used for cotton or woolen articles. To insure penetration a vacuum should be produced before the steam is admitted. Cyanide gas may also be applied in a steam chamber. This is an excellent method for destroying lice and their eggs in bundles of clothing and bedding or in baggage. Use from 143 to 285.7 ounces to 1000 cubic feet. Produce an initial vacuum of 26 inches and expose to the cyanide for at least 30 minutes. For baggage an exposure of one

hour is better. After removal bundles should be opened and aired as some of the cyanide in poisonous quantities may remain in the meshes of the cloth even though a second vacuum has been produced to assist in the removal of the gas from the chamber. Articles made of leather, such as shoes, gloves, hats, etc. may be disinfested by cyanide or immersed in gasoline or kerosene.

In the case of male persons infested with *Pediculus capitis* the hair should be clipped short. In the case of females the hair should be treated by a thorough application of a mixture of equal parts of kerosene oil and vinegar, covered with a towel for one half hour and then thoroughly washed with warm water and soap.

Body lice are to be found in the clothing particularly the seams. They attach their eggs to the fibres of the cloth. Rough cloth like woolen material, is therefore favorable to their propagation, while smooth stuffs like silk and cotton are not.

In addition to the treatment of the clothing of infested persons, it is well to wash the body with liquid soap made by boiling soap chips 1 part in 4 parts of water, and adding 2 parts of kerosene. After this mixture jellies, use by mixing 1 part with 4 parts of warm water.

Ironing clothes, particularly along the seams, with a hot iron is useful in the eradication of body lice.

Equal parts of kerosene and a 3% solution of cresol make an emulsion which is destructive to vermin.

A good remedy for pubic lice is a wash composed of 1 fluid ounce of Acetic acid (C.P.) and 3 fluid ounces of 1 to 3000 solution of bichloride of mercury.

CHAPTER XVIII

ORDER HEMIPTERA

(The True Bugs)

This is a large order of insects many of which feed on the juices of plants and may be serious plant pests; some are aquatic; some feed on insects harmful to man; some are blood suckers and are extremely annoying or even dangerous to man.

The Hemiptera have a suctorial proboscis arising from the front part of the head and folded back under the head when at rest; the labium is segmented; wings are four in number but may be wanting or vestigial, when present the hind wings are membranous and the fore wings or hemelytra, are thickened at the basal half, the apical half being membranous; the fore wings form a protecting cover to the hind wings which when at rest are folded under them; the metamorphosis is incomplete.

The blood-sucking Hemiptera which attack man are found in only two Families, the Cimicidae or true bed-bugs in which the wings are absent or vestigial, and the Reduviidae or false bed-bugs,—winged members of the Order. Closely related to the Cimicidae is the Family Polyctenidae, the so-called "many combed bugs" which are parasitic on bats.

There are some very familiar examples of Hemiptera which do not bite man but which may be very destructive to vegetation. These include the "stink bugs" (Family Pentatomidae), the "squash bugs" (Family Coreidae), the "chinch bugs" (Family Lygaeidae), the "water boatmen" (Family Corixidae), the "giant water bugs" (Family Belostomatidae), etc.

FAMILY CIMICIDAE

These are degenerate parasitic forms of insect life belonging to several genera of which three are found in the United States, namely, *Cimex*, *Oeciacus* and *Haematosiphon*. In *Cimex* the proboscis is short reaching to about the fore coxae and the anterior margin of the pronotum is deeply sinuate. In *Oeciacus* the proboscis is similar

in length to *Cimex* but the anterior margin of the pronotum is only slightly sinuate. In *Haematosiphon* the proboscis is long reaching to the posterior coxae.

Several species of the Genus *Cimex* have been described of which *Cimex lectularius* Linn. and *C. hemipterus Fabr.* (the Indian bedbug) are parsites of man subsisting on man's blood and living and breeding in his domicile. *Cimex boueti* Brumpt also is said to bite man. Two other members of the genus which are found on bats are *C. pipistrelli* Jenyns, a European species and *C. pilosellus* an American species.

Oeciacus hirundinus Jenyns and *O. vicarius* Horv. are found in swallows' nests in Europe and America respectively.

Haematosiphon inodorus Duges is a bug of poultry in Southwestern United States and Mexico. It is the only representative of the genus.

Genus Cimex

The two species closely associated with man are widely distributed members of the genus. They are domestic in their habits feeding on the blood of man and living and breeding in the cracks and crevices of beds and other furnitures, and in the walls and floors of houses. Their wings are purely vestigial and their range of movement is therefore limited. Neither do they live permanently on the host like the more parasitic insects, the lice, and are therefore only accidentally transferred from place to place in laundry or on man's clothing. Occasionally they may travel on foot from one house to another in search of food,—a matter of some yards. They ordinarily feed at night and in the absence of human blood will suck the blood of the lower animals. Occasionally they infest the animal house of a laboratory.

It is believed that the bed-bug may transmit Kala-azar. It has been incriminated in the spread of European relapsing fever and it is possible that it may rarely carry plague bacilli from man to man giving rise to small circumscribed outbreaks of the disease. In laboratory experiments plague and tuleraemia have been successfully transmitted by the bite of the bed-bug. This bug by reason of its habits must have many opportunities to take into its stomach microorganisms that may be circulating in the blood of the host, but because of its rather limited range of movement it is not so likely to give rise to widespread epidemics, such as might be produced by blood-sucking insects with more migratory habits, as for instance, mosquitoes,

flies and fleas, or lice which are continually being transported from place to place on the body of the host. Bedbugs are important factors in destroying sleep and therefore contribute to nervous strain.

The Adult. Anatomy. (Fig. 73).—The body is flattened dorso-ventrally and, as in other insects, is divided into a head, thorax and abdomen.

In *Cimex lectularius* the head anteriorly is bluntly pointed. It is widened out behind and broadly attached to the thorax, there being no distinct neck visible. At the broadest part of the head, one on each side, are the compound eyes and just anterior to these are the four-segmented antennae. The basal segment of the antenna is stout and much shorter than the others; the third segment is the longest and the fourth or terminal segment the most slender.

The proboscis at rest is carried folded back under the head and prothorax. It is composed of a labrum, two mandibles, two maxillae and a labium. The labrum is a small flap arising just dorsad of the proboscis and apparently serving as a protection to that organ at its origin. The labium is long and four-segmented, the last segment terminating in a blunt point. It serves as a sheath to protect the mandibles and maxillae which are concealed in a groove (the labial gutter) running throughout the entire length of its anterior surface,—that is its inferior surface when at rest. The mandibles are the true biting organs. They lie outside of the maxillae and closely invest them. They are articulated to a chitinous rod which runs backwards to the posterior part of the head. Distally their ends are pointed and armed with a row of recurved teeth. The maxillae play no part in making the wound in the skin but form when apposed to each other, two canals, one for the passage of the salivary juice and one for the passage of the blood which is drawn up by the action of the aspiratory pharynx. The latter is composed of two chitinous plates located in the head. It is operated by the contraction of the aspiratory muscles which arise from the inner surface of the exo-skeleton of the head dorsally and laterally and which when in action draw the dorsal plate away from the ventral plate thus sucking the blood up from the wound in the skin.

The prothorax is the most conspicuous of the three thoracic segments. Its anterior margin is concave. Its lateral borders where the tergite and sternite meet are thin and sharp, strongly convex and are produced forwards into prominent angles which reach on each side to or almost to the eye. This segment is convex dorsally and

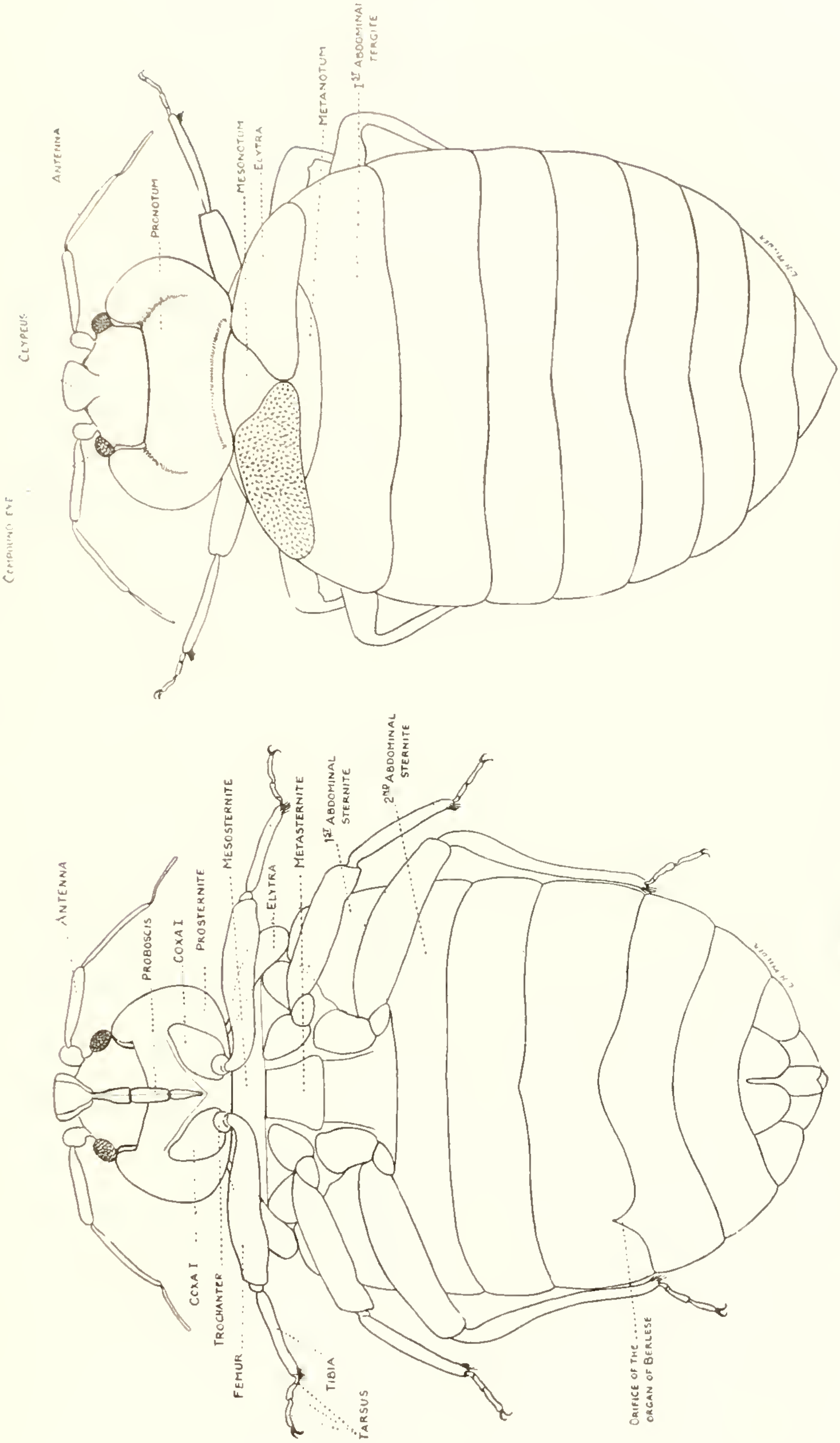

FIG. 73. *Cimex lectularius*, female, ventral and dorsal view.

flattened ventrally. The mesonotum may be observed just back of the pronotum as a small triangular area. Behind this is the metanotum which is almost concealed by the elytra, the vestiges of the first pair of wings. The elytra are articulated to the lateral portions of the mesothorax and contain many feathered hairs. Ventrally the mesosternite can be seen as a smooth transverse plate back of which is another plate, the metasternite. At the posterior border of this sternite one finds the opening of an organ of special sense. The stink glands which lie ventrally and posteriorly in the thoracic cavity, open on each side of the thorax between the bases of the second and third legs.

The legs are composed of a coxa, trochanter, femur, tibia and three tarsal segments of which the first is very small. The last segment terminates in a pair of claws. At the apical end of the tibiae is a tuft or comb of fine hairs. The lines of demarcation between the tarsal joints are not well marked.

The abdomen is rounded and is made up of ten segments, only eight of which are plainly discernible. It is widest at about the third segment. The female abdomen is more rotund and less pointed posteriorly than the male. The 9th. and 10th. segments are greatly modified because of their relation to the genital orifice and the anus. Each consists of two small sclerites situated ventrally. Between the screrites of the 9th. segment is the genital orifice and between the sclerites of the 10th. segment is the anal orifice.

Some authorities believe that the genital orifice is used only in oviposition and not in copulation. In the fourth sternite, to the right of the median line, may be seen a triangular incision which indicates the position of the opening of the organ of Berlese or copulatory pouch. This may be the opening into which the penis is inserted during copulation and the spermatozoa injected.

The body of a bedbug is generously supplied with small serrated hairs and there is a stigmatic opening on each side of the unmodified abdominal segments.

Alimentary Tract.—Blood coming up the food canal first enters the buccal cavity, a small membranous pouch, and then, passing through the aspiratory pharynx, enters the oesophagus which joins the stomach at the posterior end of the thorax. There is no proventriculus. The stomach is in two parts of which the anterior portion or cardia is the wider and contains a number of constrictions. It

passes backwards to the posterior end of the abdomen where there is a marked constriction serving as a valve and marking the beginning of the second portion of the stomach which is longer than the cardia. Its diameter is variable and it lies coiled in the posterior part of the abdomen. The hind gut is short and ends in a relatively large rectum at the anterior end of which empty separately the four Malpighian tubules, an unusual arrangement. There are no rectal papillae.

There is one pair of salivary glands located at the anterior end of the stomach. After leaving the glands each duct communicates with a salivary reservoir lying on either side of the oesophagus, and then passes forward to the salivary pump.

Eggs and Immature Forms.—The eggs are white and oval with a small projecting rim at one end surrounding the operculum. They are cemented to the surface on which they are deposited. One female may lay as many as 150 eggs or more in batches of from 6 to 50. It requires 7 to 10 days for the eggs to hatch in warm weather. Longer periods are required in cold weather. The metamorphosis is incomplete. There is no pupal stage and the young from the time of emergence from the egg resemble very closely the adult forms except that they are pale in color, smaller and the various regions of the body differ in proportions. The young grow to adults after five successive moultings over a period of 7 to 10 weeks or more, the color becoming darker and darker until fully grown. Bedbugs are capable of living perhaps for a year and for long periods without food.

CLASSIFICATION

Family Cimicidae.—The head is short and broad; the proboscis is carried in a groove on the ventral surface of head and thorax; ocelli are absent; wings are vestigial; the elytra are short and broad leaving most of the abdomen uncovered; the tarsi are three jointed.

To this Family belong the following Genera: *Cimex*, *Oeciacus*, *Cacodinus*, *Haematosiphon* and *Loxaspis*.

Genus Cimex

(Synonyms,—*Acanthia*, *Klinophilos*, *Clinocoris*)

In this genus the head is short and broad; the antennae are four-jointed the last two joints slender; the prothorax is concave in front

with its anterior angles considerably extended; the elytra are rudimentary and overlie the metathorax; the abdomen is uncovered and consists of eight visible segments, the legs are slender; the anterior tibia are more than twice as long, the posterior tibiae three times as long as the tarsi, which are three jointed.

Cimex lectularis.—In this species the lateral projections anteriorly are rounded and extend up to the eyes; the dorsum of the prothorax is convex in the middle portion with the outer lateral portions flattened; the abdomen is widest at the third segment.

This insect is cosmopolitan in its distribution although in tropical countries it may be replaced by the next species.

Cimex hemipterus.—In this insect the convexity of the prothorax extends to the margins, the lateral flattened area being inconspicuous; the abdomen is less orbicular and is widest at the second abdominal segment.

This is a common bedbug of the tropics and subtropics.

FAMILY REDUVIIDAE

The Reduviidae are winged Hemiptera called "assassin bugs" because they are predacious, sucking the blood of other insects. Some however prefer the blood of warm-blooded animals including man and are therefore important from the standpoint of preventive medicine.

All members of the family have a long, narrow head with a distinct neck; the antennae are long, slender and four-segmented; the eyes are large and prominent; ocelli are usually present; the proboscis is three-segmented, bent, and folded back under the head when at rest as in the other Hemiptera; the legs are long and the tarsus three-jointed, the prothorax is strongly developed and wings are present.

The genus *Conorhinus* (cone-nosed bugs) contains the blood-sucking species.

Reduvius personatus is of interest because it preys upon the bedbug thus securing the blood of man indirectly and in a manner less irritating to the human host.

A familiar example of the family Reduviidae is the "wheel bug" (*Arilus cristatus*) which has a prominent dorsal projection on the prothorax somewhat the shape of a cog-wheel.

No doubt all of the members of the family can bite if given the opportunity but most of them do so only through accidental contact.

Genus Conorhinus

(Synonym—*Triatoma*)

Conorhinus megistus.—This is a large bug of Brazil. It is 25 mm. or more in length, black in color with regularly arranged red markings on wings, prothorax and abdomen. It is domestic in its habits laying its eggs in cracks and holes in walls of inhabited houses. Eggs hatch in from 25 to 50 days. The young are wingless. Complete growth takes almost a year. The adults are powerful fliers. All stages bite man. They bite at night principally on the face. Children are most frequently bitten. *C. megistus* is a carrier of *Schizotrypanum cruzi* which is the cause of South American tryponosomiasis (Chap. XXX). This trypanosome passes part of its life history within the body of the insect.

Conorhinus sanguisuga.—This is the Mexican or Texas bedbug. It is 20 to 25 mm. in length. It has become a vicious biter of man although it seems that in the past it preferred to suck the juices from the common bed-bug and so has acquired a taste for human blood. It is a dark brown bug with pink markings.

Conorhinus rubrofasciatus is a bug of India which has spread to South America. It has been suggested as a carrier of kala-azar. It is dull brown in color with markings on the pronotum and with dusky yellow or brick red elytra.

Eradication

Bedbugs are very frequently difficult to exterminate, especially in situations where there are numerous cracks and crevices in which they may lurk. These are frequently overlooked, or it may be difficult to reach the bottom of the crevice with the insecticide. Perseverance, however, will usually produce the desired results. The insecticide should be applied several times at intervals of 3 to 4 days, so that any young which may have escaped destruction in the eggs will be subsequently killed.

Fumigation with either cyanide or sulphur is efficacious, but the former is dangerous and should only be used by one experienced in the process. Sulphur may be used without danger but it must be remembered that sulphur gas in the presence of moisture is liable to tarnish metals, discolor painted surfaces or bleach and weaken fabrics. Mattresses and bedding should be hung in the room.

Bureau drawers should be opened. All cracks around doors should be sealed and windows tightly closed.

Four pounds of sulphur for each thousand cubic feet should be burned in a pot surrounded by water in a tub. The pot, however, may be placed directly on an iron deck. The exposure should be about six hours.

Many solutions have been suggested for the extermination of bedbugs, and probably all of those mentioned are satisfactory provided they are applied thoroughly. Both kerosene and gasoline are effective against the insects and their eggs. These may be applied by a brush or an atomizer, always keeping in mind their inflammable nature.

Mixtures of equal parts of kerosene and 95% phenol or kerosene containing 5% of cresol will give satisfactory results when properly applied.

A mixture of equal parts of turpentine and 95% phenol has been used successfully. All mixtures must be applied lavishly with paint or varnish brushes, using a small brush for cracks in woodwork.

Bunk or bed springs and pipe frames may be thoroughly heated by gasoline torch. Boiling water is efficacious if it reaches the right spot. Mattresses may be treated with flowing steam applied with a steam hose on deck or on a fireroom or engine-room grating. After this treatment they should be dried in the sun and treated liberally with a strong solution of bichloride of mercury (saturated solution), which should be applied especially to the seams and ticking holes and allowed to dry.

It must be remembered that the cracks in walls and floors may harbor bedbugs as well as the bed or other furniture.

Other formulae which are recommended as agents to kill bedbugs are as follows:

Oil of mirbane, $\frac{3}{4}$ ounce.

Crystallized carbolic acid, $1\frac{1}{2}$ ounces.

Kerosene (or benzine), 32 ounces.

Add the oil of mirbane to the kerosene; stirring slowly; liquefy carbolic acid crystals by standing container in hot water. Then add to the mixed oils, stirring rapidly.

This mixture should be introduced into all crevices with feathers, small brushes, or small spray syringe, as a rosebush syringe, which may be purchased at a seed store. A cheap atomizer gives very satisfactory results.

For use in mattresses and beds the following may be used:

Sodium chlorid (common salt), ½ ounce.
Bichloride of mercury (corrosive sublimate) ½ ounce.
Water, 2 ounces.
Alcohol, 2 ounces.
Spirits of turpentine, 6 ounces.

Steam disinfection is the best treatment for mattresses. If a strong solution of corrosive sublimate is used as an expedient it should be borne in mind that the amount of mercury volatilizing from the bichloride at room temperature may be sufficient to cause symptoms of mercurial poisoning.

It is reported from the Sanitary Corps of the Army that bedbugs have been eradicated from officers' barracks by the use of heated air. The barracks building should be treated as a whole. All outside doors and windows should be tightly closed and inside doors left open. Thermometers should be placed here and there in the room on a level with the eye so that the temperature may be determined. The steam radiators should be turned on and the heat from this source supplemented by small oil stoves placed in each room. Fans, installed near the ceiling and pointed downward should be allowed to revolve at slow speed so that as much of the heated air as possible will be kept at the lower level where it is needed. A temperature of 140° F. can be reached in the lower parts of the room while at the ceiling it is much higher. It has been found that a temperature of 125 to 130° is sufficient to kill bedbugs and their eggs. Occasionally the procedure will have to be repeated. Mattresses, bedding and clothing should be distributed so that penetration of heat will be facilitated. Nothing should be hung near the stove because of the danger of fire. Anticipating such an occurrence fire extinguishers should be at hand and any material particularly inflammable should be removed. The exposure should be six hours. Naturally, in summer the required temperature is more easily reached than in winter.

CHAPTER XIX

ORDER ORTHOPTERA

(Roaches)

Roaches are insects belonging to the order Orthoptera, family Blattidae. There are a number of genera coming within this family, the members of which are mostly wild. They are related to the crickets. At least four species, have become domesticated and have been household pests for many years; all are found in the United States. The domesticated species are as follows:

The oriental roach (*Blatta orientalis*). This is a common roach in Europe as well as in this country. It is a large species, very dark in color, and sometimes called in Europe the "black beetle."

The German roach, or Croton bug, A European species, small in size (*Blattella germanica*).

The Australian roach, a native of Australia (*Periplaneta australasiae*). This may be differentiated from the others by the brighter and more definitely limited yellow band on the back between the head and wings and by the yellow markings on the sides of the upper wings.

The American roach of subtropical and tropical America (*Periplaneta americana*).

Cock roaches are brown or dark brown in color; the body is rather broad and flattened dorso-ventrally; the head is bent under the body and the mouth parts are directed backward, the eyes downward. The antennae are very long and slender. The insects have two pairs of wings, the outer pair being leathery. In some species the females are almost wingless, notably the oriental cock-roach. The mouth parts are well developed masticatory organs. Metamorphosis is incomplete. The eggs are not laid separately, but are gathered together within the abdomen and inclosed in a horny capsule, which is then deposited in dark cracks and crevices. When the eggs develop the capsule is split and the young emerge. The egg capsule is often carried by the mother until the eggs are about ready to hatch. Newly-hatched insects resemble the adult forms very closely,

and pass through a variable number of molts. It probably takes from six months to a year to reach full development, depending upon the species.

Roaches of different species are rarely found together, although roaches of the same species live together on very amicable terms.

Ordinarily not more than one generation per year is produced. Reproduction occurs principally during the warm weather, as roaches are particularly sensitive to cold. The abundance of roaches is apparently not accounted for so much by rapidity of multiplication as by very unusual ability to preserve themselves from ordinary means of destruction.

They are nocturnal in habits and their numbers are often not realized unless they are surprised in their midnight feasts. During the day they conceal themselves wherever protection from natural enemies and from light is afforded. Because of their shape they can squeeze into very small crevices. Occasionally they migrate and this accounts in part for the way in which new houses and offices are invaded. They are also transported with supplies. When surprised they seek shelter with a scurrying gait, and usually escape.

They are practically omnivorous. The mouth parts and jaws are strong, enabling them to eat all sorts of substances—dead animal matter, cereals, and in fact any form of food material; woolens, leather, and cloth or leather bookbindings. Occasionally they turn cannibal. Probably dead roaches frequently disappear in this way.

Anatomy of the Mouth Parts. (Fig. 73).—Heretofore all of the insects studied have had in the adult state, suctorial mouth parts. The roach is provided with masticatory mouth parts and it is probable that the specialized proboscis of the sucking insects like the Diptera has evolved from the masticatory type.

A study of the mouth parts of the roach shows it to be made up of three pairs of appendages namely, *mandibles*, *maxillae* (1st. maxillae), and *labium* (2nd. maxillae), which are adapted either to cutting or to holding solid food in the act of mastication.

The anterior flattened prolongation of the head is known as the *clypeus*, articulated to which is a flap-like process the *labrum*—really an extension of the integument covering the clypeus.

Behind the labrum are two stout, curved *mandibles*. They are broad, serrated blades attached to the gena (the lateral part of the head beneath the eye) by a joint which permits of free movement

towards the median line. When they are brought together they serve as a pair of powerful jaws. In the Orthorrhaphous flies like the Tabanidae, the mandibles have become specialized into elongated, flat cutting organs. In the Cyclorrhaphous flies the mandibles have disappeared.

Behind the mandibles are the *maxillae* (1st. maxillae) which are attached to the inferior margin of the head. The basal joint—the *cardo*—is elongated and directed transversely to the axis of the head. The second joint—the *stipes*—is articulated to the first at right

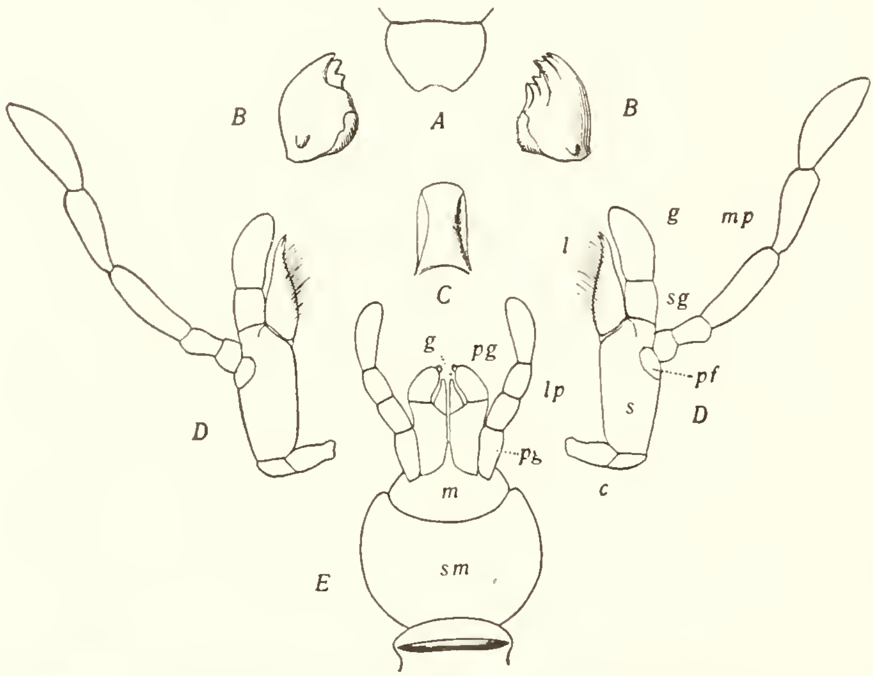

FIG. 74.—Mouth parts of a cockroach, *Parcoblatta pennsylvanica* (the common wood-roach of the United States). A, labrum; B, mandible; C, hypopharynx; D, maxilla; E, labium; c, cardo; g, (of maxilla), galea; g (of labium), glossa; l, lacinia; lp, labial palpus; m, mentum; mp, maxillary palpus; p, paraglossa; pf, palpifer; pg, palpiger; s, stipes; sm, submentum; B, D and E are in ventral aspect. (From Folsom's "Entomology," 3rd. Edition.)

angles. Its outer distal angle bears a five-jointed palpus—the *maxillary palpus*. Terminating the stipes are two processes. The anterior and outer—the *galea*—is soft and probably sensory in function. The posterior and inner process—the *lacinia*—is a cutting blade with a toothed inner edge. The piercing maxillae of the Orthorrhaphous flies together with their palpi, are homologous with the 1st. maxillae of the cockroach. In the Cyclorrhaphous flies the 1st. maxillae have disappeared, and the proboscis has evolved from the labium or 2nd. maxillae.

In the roach the *labium* (2nd. maxillae) is composed of two median plates, incompletely separated. The plate behind is known as the *submentum*, that in front, as the *mentum*. Terminating the mentum is a bilobed piece—*the ligula*. Each lobe again divides longitudinally into two portions the outer of which is known as the *paraglossa*. Between the mentum and the ligula, on each outer edge, there arises a three-jointed palpus—the *labial palpus*. It is from the labium that the proboscis of the Cyclorrhaphous flies has principally developed. It is also retained, greatly modified, in the Orthorrhaphous flies, as the labium and labellae.

The *mouth opening* of the roach lies between the labrum above, the labium below and the mandibles and 1st. maxillae laterally. The mouth leads into the *buccal cavity*, the roof of which is formed by the *epipharynx*, and the floor by the *hypopharynx*. A chitinous elevation in the hypopharynx is known as the *lingua* and beneath this is the opening of the salivary duct.

In the insects previously studied the long, slender labrum-epipharynx and hypopharynx are merely prolongations of the homologous structures in the roach.

Internal Anatomy.—The *oesophagus* which communicates with the buccal cavity by a small opening, passes through the neck and thorax, gradually widening into a *crop* which lies in the abdomen. The *proventriculus* which separates it from the stomach, is a thick walled, pear-shaped organ. Its chitinous lining is elevated into six broad teeth between which are smaller tooth-like ridges. The *stomach* or *ventriculus* is a wide, elongated tube, the anterior end of which is provided with seven or eight diverticula. The *Malpighian tubules*, 20 or more in number, empty into the intestine at its junction with the stomach. The *intestine* has been divided into the *ilium*, *colon* and the *rectum* in which may be seen the six socalled *rectal glands*,—ridges projecting into its interior and well supplied with tracheae.

The *salivary glands* two in number lie on either side of the oesophagus and crop. They are about one fourth of an inch long. Their ducts unite beneath the suboesophageal ganglion into a *common duct* which empties into the floor of the buccal cavity beneath the lingua. There are also two *salivary receptacles* which are elongated, oval sacs situated at the end of a long duct. The ducts from the sacs unite with each other and then with the ducts of the salivary glands to form the *common duct*. The ducts of glands and receptacles are lined with chitin arranged spirally.

Roaches by preference infest bakeries, kitchens, pantries, storerooms and toilets. They follow water and drain pipes.

Roaches are a sanitary menace, because they are potential carriers of infection mechanically by means of their feet and bodies. They soil everything they come in contact with, leaving a nauseous, roachy odor. It is thought that the roach is the intermediate host for a tape worm (*Davainea madagascariensis*) which has been found in man. Roaches also act as the intermediate host of the Nematode Gongylonema, which is associated with cancer of stomach of rats.

The total elimination of roaches is difficult. Scrupulous cleanliness and the keeping of food and food remnants in places inaccessible to the roach is of prime importance. All unnecessary corners, cracks and imperfections in the structure of the building which favor breeding or furnish hiding places must be eliminated or treated with roach poison.

Eradication

The best poison is sodium fluoride. Sodium fluoride powder must be liberally sprinkled or blown by means of a powder blower into corners, drawers, closets and other places of concealment. It must be distributed in such a way that it will not be swept up or removed. It should be allowed to remain and act for weeks at a time. It can be sprinkled along the back parts of shelves and out of the way in the recesses of drawers, in file cases, etc. This substance is not injurious to books or other materials. It forms the basis of most roach powders on the market. The roaches walk in it and then lick it off their feet.

Large numbers of roaches may be destroyed in places heavily infested by means of traps. A simple form of trap consists of a deep smooth basin or jar with a stick leading up to the top as a runway from which they slip into the trap. The trap may be baited with mucilage or sweetened meal or other food material.

A dish containing 1 part of dry and thoroughly powdered plaster of paris to 3 or 4 parts of flour well mixed may be placed near a dish of water. The insects eat the mixture, become thirsty and drink. The water sets the plaster of Paris which then clogs the intestines.

These expedients will destroy large numbers of roaches in suitable places, but gradual elimination of the insects by means of sodium fluoride properly distributed is the most effective measure in the long run and the one most generally practicable.

Arsenic does very little good, as roaches are wary and shun the poison bait. Phosphorus has been used successfully in the shape of a paste. This may be purchased as a proprietary preparation. *Pure borax* is at times used with great success. It may be used alone or in a mixture consisting of 1 part of powdered borax and 3 parts of finely pulverized chocolate, freely sprinkled around infested places. Fumigation by hydrocyanic-acid gas or by sulphur dioxide will destroy roaches. Fumigation, however, may not destroy the eggs, which subsequently hatch making a second fumigation necessary.

Carbon bisulphide is also of value as a gaseous insecticide, but it must be used with caution as it, like hydrocyanic-acid gas, is poisonous to human beings and domestic animals.

Flowers of sulphur used in the same way as sodium fluoride will act as a repellant but is not nearly so satisfactory as the fluoride.

CHAPTER XX

CLASS ARACHNIDA

To this Class belong the spiders, scorpions, mites and a few other less important groups. The spiders and scorpions are not parasitic and are only troublesome to man by reason of the bite or sting which they may be capable of giving through the mouth parts (chelicerae), or a special stinging apparatus as in the tail of the scorpion. The members of the class which are far more important from the standpoint of medical entomology belong to the Order Acarina, or mites, a number of which are parasitic and cause disease through infestation or by actually carrying the causative agent of disease from one animal to another. In the following table only those mites are mentioned which in one way or another produce pathological reactions in man with more or less frequency. It must be remembered, however, that there are other mites which will occasionally be found on man and which may actually bite him.

Superfamily	Family	Genus and Species
Ixodoidea	Argasidae	*Ornithodoros moubata*, *Ornithodoros savignyi*, *Ornithodoros turicata*, *Ornithodoros talaje* (Relapsing fever ticks)
	Ixodidae	*Dermacentor andersoni* (Rocky Mountain spotted fever tick)
Demodicoidea	Demodecidae	*Demodex folliculorum* (Follicle Mite)
Sarcoptoidea	Sarcoptidae	*Sarcoptes scabei* (Itch mite)
	Tarsonemidae	*Pediculoides ventricosus* (Straw itch mite)
	Tyroglyphidae	*Glyciphagus domesticus* (in sugar, cause of grocers itch) also *Tyroglyphid* mites in flour and other food stuffs.
Parasitoidea (Gamasoidea)	Dermanyssidae	*Liponyssus bacoti* (a rat mite)
		Dermanyssus gallinae (a poultry mite)
Trombidoidea	Trombidiidae	*Microtrombidium pusillum* (a chigger of Europe)
		Trombicula akamushi (Tsutsugamushi fever mite of Japan)
		Trombicula irritans (Chigger of Mexico and the United States)
Eupodoidea	Eupodidae	*Tydeus molestus* (may attack man similar to chigger)

ORDER ACARINA

(The Mites)

In this Order there is little differentiation between the head and thorax and these are therefore spoken of together as the cephalothorax. This is broadly united to the abdomen with often no clear line of demarkation. There are no antennae. The abdomen usually shows no evidence of segmentation. In their life history the acarines typically pass through four stages—egg, larva, nymph and adult. The adult and nymph have four pairs of legs, the larva has but three pairs.

While the mites vary greatly in size, shape and color, the points which are common to all acarines are usually sufficiently characteristic to group them without great difficulty.

Mites are found everywhere if one will only look for them. Some are parasitic on animals, many are not. Some live on the juices of plants or insects; some produce galls; some live in water—fresh and salt; some live in humus and may be found in rotting leaves. Others live on fruits, in cheese, flour, sugar etc.; others prey upon their own kind. Some are parasitic on insects, birds, mammals and reptiles; some eat the epidermal scales or feathers or hairs, others burrow under the skin, some live within the follicles, others suck blood. They have been found in the bronchial passages of monkeys, in the air sac of snakes, in the bark of trees and in the dust from the floor.

External Anatomy.—The anatomy may be described briefly as follows; (Fig. 75).

In many mites the back is covered in whole or part by a corneous shield known as the *scutum.* At the anterior edge of this may be seen a small, subtriangular or rectangular piece known as the *capitulum*, which can not always be detected with ease. It supports the mouth parts. The mouth parts consist of a pair of *mandibles* or *chelicerae*—often styliform or needle-like,—sometimes chelate or clawed,—and a pair of *palpi.* A *lip* or *labium* may be formed by a union of the basal joints of the palpi. In many species additional mouth segments can be seen. There may be a central piece known as the *hypopharynx* which is a prolongation of the aspiratory pharynx; an upper plate known as the *epistome* and an under plate spoken of as the *hypostome.* The latter is especially marked in the ticks. It is in two halves and in the ticks is covered with small recurved teeth. The *palpi* are never more than *five-jointed.* They

are sensory organs, although in some species they are modified for clasping. The last joint may be hairy or it may terminate in a spine, hook, or claw.

One or more pairs of simple *eyes* (ocelli) may be present on either side of the cephalothorax or the scutum. Rarely there may be only a median pair of eyes.

The adult mite usually has *four pairs* of *legs* composed of from three to *seven segments*. The following segments can usually be seen;—beginning with the segment attached to the body they are, *coxa, trochanter, femur, patella, tibia* and *tarsus*. The legs are haired or spined to a greater or less degree and the last joint or tarsus terminates in one to three *claws* or *ungues* and a *sucker* (*pulvillus* or *caruncle*), at times a pulvillus and no claws. In some species the two posterior pairs of legs are located so far removed from the two anterior pairs that they appear to arise from the abdomen.

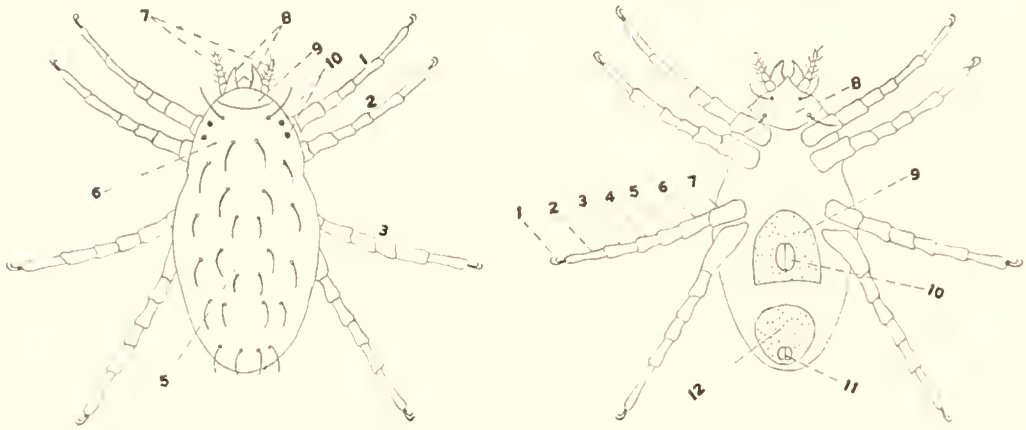

FIG. 75.—A mite (semidiagrammatic) showing the external anatomy. (After Banks.) Dorsal view: 1. Leg I. 2. Leg II. 3. Leg III. 4. Leg IV. 5. Abdomen. 6. Cephalothorax. 7. Palpi. 8. Mandibles. 9. Capitulum. 10. Eyes. Ventral view: 1. Claws. 2. Tarsus. 3. Tibia. 4. Patella. 5. Femur. 6. Trochanter. 7. Coxa. 8. Beak. 9. Genital plate. 10. Genital aperture. 11. Anal aperture. 12. Anal plate.

Many of the mites are softbodied. In addition to a dorsal shield or scutum some are provided with chitinous *plates* or *shields* ventrally. The body is usually supplied with *hairs, bristles* or *scales* arranged in a manner characteristic of the species. The *anal aperture* is located on the ventral surface near the tip of the abdomen. The *genital aperture* of the male (epiandrum) as well as of the female (vulva or epigynum) is usually on the ventral surface anterior to the anal opening usually between the fourth pair or hind legs (leg IV). In some species the genital segment is pushed so far forward that the genital aperture is close to the mouth.

Internal Anatomy.—The alimentary canal is composed of a *pharynx* or aspiratory organ to which are attached the aspiratory muscles; an *oesophagus;* a *stomach* with its *cocca;* a narrow *intestine* and a *rectum.* The *two malpighian tubules* empty into the rectum. *Salivary glands* are located in the cephalothorax.

The breathing or *tracheal openings* in some species are wanting. In others the spiracles are located on each side of the cephalothorax, while in others the respiratory system opens into the *coxal cavities* (acetabula), or by an orifice in what is known as a *stigmal plate* located on each side near the fourth coxae.

Life History of Mites.—In the life history of mites there are typically four stages—egg, larva, nymph and adult. Most mites deposit eggs, some are viviperous and one, *Pediculoides ventricosus*, gives birth to adult males and females.

The larva which emerges from the egg is active, has but three pairs of legs, and no genital orifice. After feeding awhile it becomes quiescent. A fourth pair of legs develops, usually the hind pair, and the larva after a moult then becomes a nymph with four pairs of legs and breathing spiracles but no genital orifice. During the nymphal stage the mite grows by moulting one or more times, then becomes quiescent, and finally, after undergoing a final moult becomes the fully formed adult.

There is often a curious nymphal stage in the life history of some mites, especially the Tyroglyphidae, in which the body becomes hard and chitinous, there is an absence of a mouth orifice and distinct mouth parts, the legs are short and poorly adapted to walking and an arrangement of sucking discs develops on the ventral surface near the tip of the abdomen. By the aid of these discs the Hypopus, as it is called, clings to an insect until it is transported to a place favorable to its development into an adult mite.

Ticks.—Of all mites, the ticks or giant mites are most familiar. They are all temporary parasites of warm blooded animals and of birds and have been taken from snakes and tortoises.

The body is leathery and in the female is capable of great distension when engorged with blood and full of eggs.

In most of the ticks a dorsal shield or *scutum* is present. This in the male covers the entire back but in the female only a small part in front. Just anterior to the scutum may be seen the *capitulum* which is composed of the basal part or *basis capituli* and the mouth segments. These are, *two four-jointed palpi; two mandibles*

with their *sheaths*, and a *hypostome*. The *mandibles*, *mandibular sheaths* (lying dorsal to the mandibles) and the *hypostome* together form the *proboscis* or *haustellum*. At the tip of the mandibles are two processes known as the *digits* or *apophyses*. The under surface of the hypostome is furnished with stout teeth. The mandibles and hypostome are the piercing organs which are inserted into the skin when the tick feeds. The food channel is formed by the dorsal surface of the hypostome and the ventral surface of the mandibles.

The inner surface of the palps is more or less concave. The palpi vary in length and shape. The first and last joints of the palpi are not always easily seen, as the first or basal joint is short and broad, and the last joint is very small indeed, located at the end of the third joint, often in a depression. The shape of the palpi and the shape of the basis capituli are both of taxonomic value. On the dorsum of the capitulum of adult female Ixodid ticks may be seen two depressed pitted areas known as the *porose areas*. Their function is unknown. They are seen only in the female adult forms of the Ixodidae—never in the larval or nymphal stages.

The posterior edge of the body is frequently marked by *furrows* giving a lobed or *festooned* appearance. The *scutum* is often *ornamented* with whitish, silvery or yellowish streaks or spots, when without, the tick is said to be *inornate*. It has two longitudinal grooves known as the *cervical grooves*. On the dorsum of the abdomen about the middle there may be seen in some genera two small circular or oval plates called the *dorso-submedian porose plates* or *fovea*. Their purpose is unknown.

On the ventral surface, the *genital opening* may be seen located anteriorly well towards the capitulum. Posteriorly, towards the tip of the abdomen, is the *anal opening*. The ventral surface is marked by *grooves*. In some forms there is a *post-anal groove*. In others a *groove anterior* to the anal opening. In all ticks it is usually possible to detect a groove on each side of the anal aperture. *Ventral plates* or *shields* are present in the males of some genera. These plates may be closely applied to the body and level with the integument when they are spoken of as non-salient plates, or, they may project more or less from the body.

Each leg has *six joints* namely, *coxa*, *trochanter*, *femur*, *tibia*, *metatarsus* and *tarsus*. The tarsus terminates in *two claws* and a *pulvillus*, or the pulvillus may be rudimentary or absent. The first coxa is often *bifid*. One or more of the coxa may be *spined*.

On the upper surface of tarsus I (the tarsus of the first or most anterior leg) may be seen a pit known as *Haller's organ* possibly an organ of hearing.

Above and behind the last or hind coxa (or in front of this coxa in the Argasid ticks) may be seen the *stigmal plate* (one on each side) which contains the *stigma*, or *tracheal orifice* or *breathing spiracle*. The shape and the minute structure of the stigmal plates have taxonomic value. A section of the stigmal plate of the genus *Dermacentor*, for instance, is, according to Stiles, composed of three layers. Chitinous, goblet-like structures are to be observed, the stem of the goblet forming the internal layer, the rim and upper part forming the external layer and the lower part of the bowl of the goblet forming the middle layer. Interspersed between these goblet-like structures are smaller, supporting, chitinous structures of circular to elongate form. On surface view the stigmal plate has the appearance of being granular. The larger granules are the goblet-like structures seen on cross section. They vary in size and number according to the species. The smallest granules are the small, chitinous, supporting structures.

Internal Anatomy.—The *mouth* which is located between the hypostome below and the mandibles above, after passing backwards for a distance as the *buccal cavity*, ends blindly. A V-shaped opening in its floor communicates with the *aspiratory pharynx* and on each side posteriorly there is the opening of the *salivary ducts*. The *pharynx* is continuous with a narrow *oesophagus* which opens into the floor of the *midgut* or *stomach*. This is the central food reservoir which gives off *diverticula*, anteriorly, posteriorly and laterally. The stomach is connected to the *rectum* by a very fine, practically functionless, *intestine*. The *rectum* is saccular and has emptying into it, the two, long, fine, convoluted *Malpighian tubules*. Thus it would seem that the rectum serves more as a uninary bladder than as a true fecal reservoir.

The *salivary glands*, two in number, lie over the bases of the first pair of legs. Other unicellular salivary glands may also be present. Their ducts empty into the main salivary duct.

Dermal glands are present and there is a socalled *cephalic gland* in the head and *coxal glands* in the second coxal joint which empty through a minute pore in the first coxal joint.

Lying behind the midgut is a single *ovary*. There are two coiled *oviducts* connecting with a *spermatheca* and ending at the genital orifice.

In their metamorphosis ticks like other acarines, pass through the four stages of egg, larva, or "seed" tick, nymph and adult. All stages after hatching feed on blood.

Classification of Mites

The Acarina have been classified in several ways. Canestrini has divided them into suborders according to the location of the stigmatic opening, as follows:

Astigmatic:—Those which have no stigmatic openings but breathe through the skin. (Tyroglyphid and Sarcoptid mites.)

Prostigmatic:—Those with spiracles at the sides of the beak. (Trombidioidea and Eupodoidea.)

Mesostigmatic:—Those with a spiracle above and slightly in front of the fourth coxa, with a peritreme extending forward. (Parasitoidea.)

Metastigmatic:—Those with a spiracle located above and behind the fourth coxa. (Ixodoidea—the ticks.)

Cryptostigmatic:—Those with tracheal openings into the acetabula of the legs. (The Oribatid mites.)

Hydracarina:—The water mites.

Nathan Banka has classified the Acarina by dividing them into eight superfamilies. His key to these and to the families is as follows:

Synopsis of Superfamilies (Nathan Banks)*

1. Abdomen annulate, prolonged behind; very minute forms; often with but four legs..Demodicoidea
   Abdomen not annulate nor prolonged behind; always with eight legs......2
2. With a distinct spiracle upon a stigmal plate on each side of the body (usually below) above the third or fourth coxae or a little behind; palpi free; skin often coriaceous or leathery; tarsi often with a sucker...................3
   No such distinct spiracle in a stigmal plate on this part of body...........4
3. Hypostome large, furnished below with many recurved teeth; venter with furrows; skin leathery; large forms, usually parasitic........Ixodoidea
   Hypostome small, without teeth; venter without furrows; body often with coriaceous shields, posterior margin never crenulate; no eyes. Parasitoidea
4. Body usually coriaceous, with few hairs; with a specialized seta arising from a pore near each posterior corner of the cephalothorax; no eyes; mouth parts and palpi very small; ventral openings of the abdomen large; coxae all close together; never parasitic; tarsi never with a sucker. Oribatoidea
   Body softer, without such specialized seta...............................5

* This key and others by Nathan Banks, from The Acarina or Mites. Report No. 108, Dec. 1915, Bureau of Entomology, U. S. Department of Agriculture.

5. Living in water. . . . . Hydrachnoidea
Not living in water. 6
6. Palpi small, three-jointed, adhering for some distance to the lip; ventral suckers at genital opening or near anal opening usually present; no eyes; tarsi often end in suckers; beneath the skin on the venter are seen rod-like epimera that support the legs; body often entire; adult frequently parasitic
Sarcoptoidea
Palpi usually of four or five joints, free; rarely with ventral suckers near genital or anal openings; eyes often present; tarsi never end in suckers; body usually divided into cephalothorax and abdomen; rod-like epimera rarely visible; adults rarely parasitic. 7
7. Last joint of palpi never forms a "thumb" to the preceding joint; palpi simple, or rarely formed to hold prey; body with but few hairs.
Eupodoidea
Last joint of palpi forms a thumb to the preceding, which ends in a claw (a few exceptions); body often with many hairs. . . . . Trombidioidea

Synopsis of Families

Demodicoidea

With but four legs, of five joints each; living on plants, often in galls.
Eriophyidae
With eight legs, of three joints each; living in skin of mammals. . . . Demodicidae

Sarcoptoidea

1. With tracheae; no ventral suckers; legs ending in claws; body divided into cephalothorax and abdomen; the female with a clavate hair between legs I and II; not parasitic on birds or mammals. . . . . Tarsonemidae
Without tracheae; no such clavate hair. 2
2. Genital suckers usually present; not parasitic on birds or mammals; skin usually without fine parallel lines. 3
Genital suckers absent; parasitic on birds or mammals; skin with fine parallel lines. 4
3. Legs short, without clavate hair on tarsi I and II; living on insects.
Canestriniidae
Legs longer, with clavate hair on tarsi I and II; not parasitic (except on bees).
Tyroglyphidae
4. Possessing some specially developed apparatus for clinging to hairs of mammals. . . . . Listrophoridae
Without such apparatus. 5
5. Living on plumage of birds. . . . . Analgesidae
Not on plumage of birds, but on living tissues. 6
6. Vulva longitudinal; in skin and cellular tissue of birds. . . . . Cytoleichidae
Vulva transverse; in skin of mammals and birds . . . . Sarcoptidae

Parasitoidea

1. Palpi with the last joint enlarged; a spiracle situate above coxa III. Holothyridae
   Palpi not enlarged at tip; spiracles situate behind coxa III. 2
2. Genital aperture near the anus; mouth parts retractile within a large buccal cavity, which is situated in an anterior part of the body separated by a suture from the rest of the body. Spelaeorhynchidae
   Genital aperture not or scarcely behind the hind coxa; no anterior part of body separated by a suture. . . . . Parasitidae

Oribatoidea

1. No division between cephalothorax and abdomen. . . . . . Labidostommatidae
   A suture between cephalothorax and abdomen. 2
2. Cephalothorax movably attached to the abdomen; palpi four-jointed. Hoplodermidae
   Cephalothorax not movable; palpi five-jointed. . . . . Oribatidae

Ixodoidea

1. No scutum; no ventral shield; mouth parts of adult not prominent from above; no pulvillus to tarsus in adults. . . . . Argasidae
   Scutum present; sometimes ventral shields; mouth parts of adult prominent from above; pulvillus to tarsus of adults. . . . . Ixodidae

Trombidioidea

1. Legs I and II with processes bearing spines; skin with several shields; coxae contiguous. . . . . Caeculidae
   Legs I and II without such processes; few, if any, shields. 2
2. Mandibles chelate or uncinate, that is a basal rather thickened part, with a claw near its tip. 3
   Mandibles stylate (needle-like), and retractile; coxae in two groups. 4
3. Tarsal joint of leg I usually enlarged; usually a crista metopica on cephalothorax; coxae in widely separated groups. . . . . Trombidiidae
   Tarsal joint of leg I not enlarged, often long; no crista metopica; coxae usually in one group, contiguous. . . . . Anystidae
4. Tarsi enlarged; usually a dorsal groove; adults free. . . . . Erythraeidae
   Tarsi not enlarged; no dorsal groove. 5
5. Phytophagous occurring on plants; often spinning threads; palpi simple; leg I never ending in long hairs; all legs with claws; bristles usually simple Tetranychidae
   Predaceous or parasitic, often on birds or mice; palpi often enlarged at base and forming a forceps; claws often absent from one or more pairs of legs; often with pectinate bristles. . . . . Cheyletidae

Eupodoidea

Palpi simple: mouth parts hidden by a hood; no apparent division of body, and no bristles above; last joint of leg I but little longer than preceding. Cryptognathidae

Palpi often geniculate, or else fitted for grasping prey; mandibles large and snout-like; cephalothorax with four long bristles above, two in front, two behind; last joint of leg I longer than preceding joint, often twice as long..Bdellidae

Palpi never geniculate, not fitted for grasping prey; beak small; cephalothorax with bristles in different arrangement; last joint of leg I shorter or but little longer than preceding joint; eyes, when present, near posterior border. Eupodidae

Hydrachnoidea

(Water Mites)

Mouth parts carried upon a distinct beak; no ventral suckers; living in the sea...Halacaridae

Mouth parts not carried upon a beak; usually suckers near the genital openings; usually in fresh water.........................Hydrachnidae

Superfamily Ixodoidea Banks 1894

(The Ticks)

The Ixodoidea are acari having their breathing spiracles located near the fourth coxae (Metastigmatic). They are characterized by having a movable false head or capitulum which is composed of a basal portion or basis capituli, a pair of four-jointed palpi, protrusible mandibles terminating in two or three serrated digits or apophyses, and a rigid hypostome toothed on its under surface. All subsist on the blood of animals. Most of them will probably bite man under the proper conditions, many of them have been known to bite man, and a number of them transmit certain diseases of man and animals, including relapsing fever of Africa, Persia, Central America and South America; Rocky Mountain spotted fever; piroplasmosis and spirochaetosis of animals and birds.

The superfamily has been divided into two families, the Argasidae and the Ixodidae. The differences between them have been tabulated by Nuttall as follows:

	Argasidae	Ixodidae
Sexual dimorphism	Slight.	Marked.
Capitulum:		
Base	Ventral in camerostome. No porose areas in female.	Anterior; porose areas in female.
Palps	Leg-like with subequal articles.	Relatively rigid, of varied form, 4th. article rudimentary.
Body:		
Scutum	Absent.	Present.
Festoons	Absent.	Generally present.
Eyes (when present)	Lateral, on supracoxal folds.	Dorsal, on the sides of the scutum.
Spiracles	Very small, more anterior.	Generally large, well behind coxa IV.
Legs:		
Coxae	Unarmed.	Generally armed with spurs.
Tarsi	Without ventral spurs.	Generally armed with one or two ventral spurs.
Pad (pulvillus)	Absent or rudimentary.	Always present.

Key to the Genera of the Family Argasidae

1. Margin of body flattened, sharp-edged................................*Argas*
   Margin of body thick, rounded, not clearly defined (Fig. 77)...*Ornithodoros*

Key to the Genera of the Family Ixodidae

1. Venter showing a groove surrounding the anus in front and extending backwards to hind margin of abdomen; no festoons; no eyes; palpi of variable form without projecting transverse ridges or sharp angles; stigmal plates nearly circular; venter of male with nonsalient plates (Fig. 78).
   Ixodes Latreille 1795 (*ricinus*)*
   Venter with a distinct groove behind the anus but none in front, at times this groove vestigal or absent; usually with festoons present in male more or less distinct in female; eyes present or absent; stigmal plates rounded to comma-shaped; palpi long or short, smooth, ridged or angled on sides; ventral plates present or absent in male..............................2
2. Palpi short, relatively broad, second article not especially longer than wide.3
   Palpi long, relatively slender, second article distinctly longer than wide....7
3. Palpi with acute transverse ridges dorsally and laterally; festoons absent or only faintly indicated; stigmal plates rounded or oval; male with ventral plates; post anal groove very faint or obsolete (Fig. 79).
   Boophilus Curtice 1891 (*annulatus*)
   Palpi not ridged as above; festoons practically always present in male; more or less distinct in female; stigmal plates rounded to comma-shaped; post anal groove distinct; male with or without ventral plates..........4
4. Second article of palpi acutely produced outwardly at base extending beyond basis capituli; eyes absent; male without ventral plates (Fig. 81).
   Haemaphysalis Koch 1844 (*concinna*)

* The specific name in parenthesis is the type of the genus.

Second article of palpi not so produced; eyes present; with or without ventral plates 5

5. Basis capituli rectangular dorsally; usually ornate; coxa IV in male much the largest; male without ventral plates or shields (Fig. 82).
Dermacentor Koch 1844 (*reticulatus*)

Basis capituli hexagonal dorsally having prominent lateral angles; usually inornate 6

6. Coxa IV much the largest; male without ventral plates or shields.
Rhipicentor Nuttall and Warburton 1908 (*bicornis*)

Coxa IV normal; male with ventral plates and may show a caudal protrusion (Fig. 84) . . . . *Rhipicephalus* Koch 1844 (*sanguineus*)

7. Eye present 8

Eye absent or vestigial 9

8. Eyes within scutal margin; ventral shields present in male and two posterior abdominal protrusions capped by chitinous points; basis capituli subtriangular dorsally; with or without ornamentation; with or without festoons.
Hyalomma Koch 1844 (*aegyptium*)

Eyes marginal; ventral shields absent except occasionally small plaques are present close to the festoons; festoons always present; usually ornate (Fig. 86) . . . . *Amblyomma* Koch 1844 (*cajennense*)

9. Similar to *Amblyomma* but body frequently very broad; eyes absent or vestigial . . . . (Subgenus) *Aponomma* Neumann 1899 (*gervaisi*)

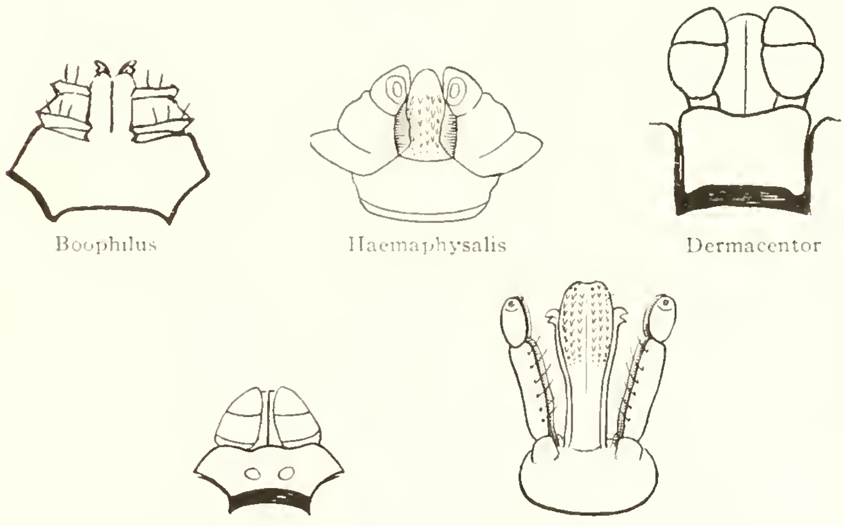

FIG. 76.—Capitulum of the more important genera of Metastriatic Ixodidae.

FAMILY ARGASIDAE

Genus Argas Latreille 1796

In this genus the body is flattened and oval or rounded, with a flattened, sharp-edged margin which is distinct even when the tick is

replete; the capitulum is entirely invisible from above; there are numerous symmetrically arranged oval or rounded discs on the dorsum and the venter, disposed in radial lines; the integument is minutely wrinkled; eyes are absent.

Argas persicus Oken is the "Miana bug" of Persia. It may live in houses and is found on fowls. It is said that severe symptoms may follow its bite. This tick is found in many parts of the world. In the United States it is known under the name of *Argas miniatus* Koch. It is quite common on chickens and has a more Southern distribution. In Brazil, the Soudan and in other parts of the world it transmits a spirochaetosis of chickens.

Argas reflexus Fabricius is a pigeon tick of Europe which has been known to bite man.

Another genus, *Caris*, has been suggested for those Argas ticks, which are parasitic on bats and which have a body as broad or broader than long and a transverse groove behind the anus.

Genus Ornithodoros Koch 1844

In this genus the body is flat in the unfed tick but decidedly convex when fed; the margin is thick and not clearly defined; the anterior end is bluntly pointed and hood-like; the anterior portion of the capitulum is often visible from above; when discs are present they are not arranged radially; grooves and folds are present on the venter; eyes may be present or absent.

Some of the ticks in this genus are responsible for the transmission of relapsing fever. They are tropical and subtropical in their distribution and at least four are found in America. These ticks as well as those of the genus *Argas* are more like bugs in their habits.

Ornithodoros moubata Murray (Fig. 77) is the carrier of relapsing fever of Africa, or African tick fever as it is sometimes called. It also possibly transmits *Filaria perstans* (Chap. XXXV.) These ticks live in the cracks and crevices of walls and floors or in the gravel floors of native huts and rest houses, coming out at night to feed. The larval stage is passed in the egg, a nymph emerging after an incubation of about twenty days. The adult ticks moult several times and may live for at least a year.

Ornithodoros savignyi Audouin is common in Africa, India, Persia and Aden. It will attack man and is responsible for the transmission of Persian relapsing fever. (Chap. XXXV.)

Ornithodoros talaje Guerin-Meneville is the carrier of relapsing fever of Panama. (Chap. XXXV.) It is found in Central and South America, Mexico and the Southern United States. It also lives in houses its habits being similar to those of *O. moubata*. Because of the presence of a lateral flap on each side of the mouth parts which other members of the genus *Ornithodoros* do not have, a subgenus, *Alectorobius*, has been proposed for this species.

Ornithodoros megnini Dugés is the "spinose ear tick" of Mexico and the United States. It is found on cattle and other domestic animals, rabbits, etc., and occasionally on man. The adult rarely feeds and its mouth parts are weak but the nymph takes enough

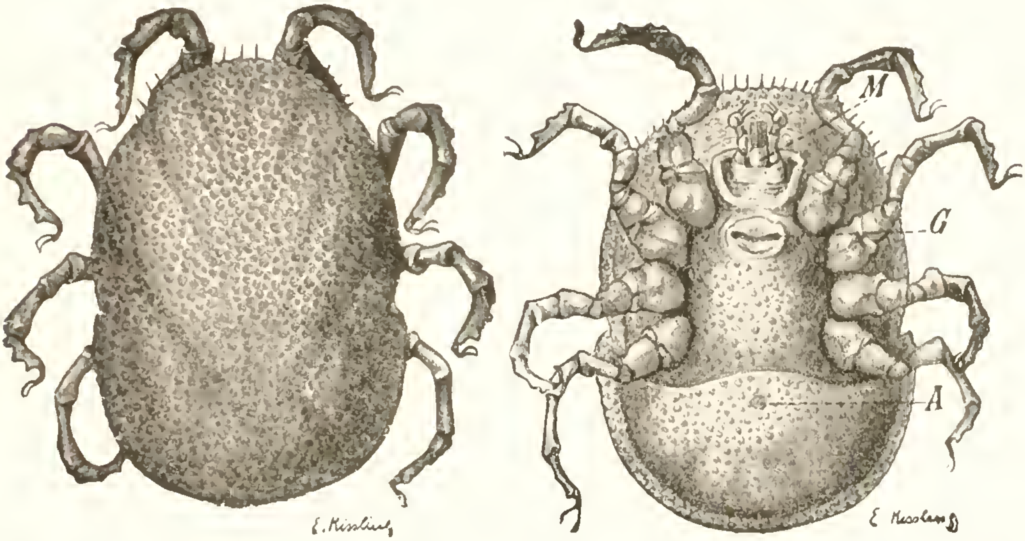

FIG. 77. *Ornithodoros moubata*, dorsal and ventral view. (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology," 7th. Edition.)

food to last through the adult state. When replete it drops to the ground. The last moult, mating, and ovipositing occur off the host in cracks and crevices in trees, walls, fence posts and the like. After laying her eggs the female dies, but until she has been fertilized may live for many months. After emerging from the egg the larval ticks await the opportunity to attach themselves to an animal preferring the inside of the ear as a feeding ground, hence the common name "ear tick." This tick, unlike others of the genus, has a spiny vestiture and for this reason as well as because of the modifications in its life history, some authorities have placed it in a subgenus, *Otobius*.

Ornithodoros turicata Dugés is another tick of the Southern United States, Mexico, Central and South America. It attacks hogs, small mammals and man and may be found in houses. It is the carrier of South American relapsing fever. (Chap. XXXV.)

Ornithodoros coriaceus Koch is found in California and Mexico and will bite man. Its bite is followed by a severe reaction.

The Following Key May Be Used to Identify the American Species of Ornithodorus (After Banks)

1. Body provided with many short, stiff bristles; hind tarsi scarsely three times as long as broad at base, with one subterminal hump above; anterior tarsi also with one subterminal hump; body rounded in front; no eyes. *O. megnini*
   Body without bristles, but covered with rounded tubercles or granules; hind tarsi more slender.......... 2
2. Two pairs of eyes present on each side above coxae II; tarsi IV with a prominent subterminal spur above; front of body conical in the middle; leg I strongly roughened.......... *O. coriaceus.*
   No eyes; no such spur on hind tarsi.......... 3
3. Front of body conical in middle; tarsi I without humps above; a lateral flap on each side of mouth parts.......... *O. talaje*
   Body rounded in front; tarsi and metatarsi each with three humps; no lateral flap on each side of mouth parts.......... *O. turicata*

FAMILY IXODIDAE

Genus Ixodes Latreille 1796

This genus is characterized by being inornate, without eyes and without festoons; the spiracles are round or oval; the anal groove surrounds the anus in front; the shape of the palpi and basis capituli is variable; the tarsi are without spurs; the venter is covered by nonsalient plates as follows, one pregenital, one median, one anal, two adanal, and two epimeral. (Fig. 78.)

In general the palpi of most Ixodes are rather slender, the third joint is longer than broad and tapers towards the tip. They are also narrow at the base so that there ordinarily is a distinct interval on each side between them and the base of the hypostome. The basis capituli is usually not angulate at the sides. For a group of ixodes which has the basis capituli slightly angulate at the sides and the third joint of the palpi shorter than broad and broadly rounded at the tip, another genus, *Ceratixodes*, has been adopted by some

authorities. A few species have been described from sea birds living in Arctic and Antarctic regions. For another group of Ixodes, on bats and which have the legs unusually long, the genus *Haemalastor* has been suggested.

A number of species of Ixodes have been reported from the United States among them being *Ixodes ricinus* Linn. which has a

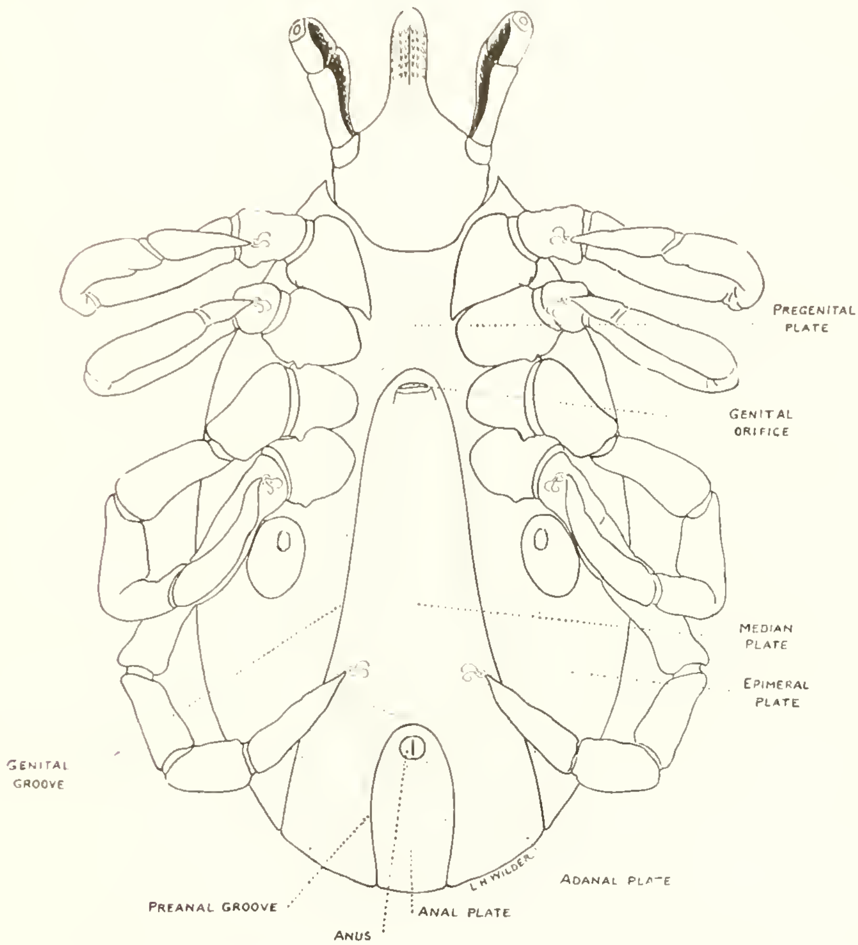

FIG. 78.—A tick of the genus *Ixodes*, male, ventral view.

wide distribution and in Scotland is believed to be responsible for the spread of a disease of sheep.

It has been taken from a variety of domestic animals as well as from deer and some of the smaller wild animals and birds. It will bite man.

This tick drops to the ground between each one of its successive stages, thus each time it is compelled to seek a new host.

Genus Boophilus Curtice 1891

This genus contains the well known Texas fever tick, *Boophilus annulatus* Say (*bovis* Riley) (Figs. 79,–80) which transmits Texas or red water fever among cattle. The disease is caused by a blood parasite, *Babesia bigemina*, which is ingested with the blood when the tick feeds and is transmitted by the adult female tick to her offspring. Thus even young ticks which have not fed may carry the disease.

The genus is characterized by being inornate and without festoons; eyes are present; the palpi are short and ridged dorsally and laterally; coxa I is bifid; the scutum is small; the anal groove

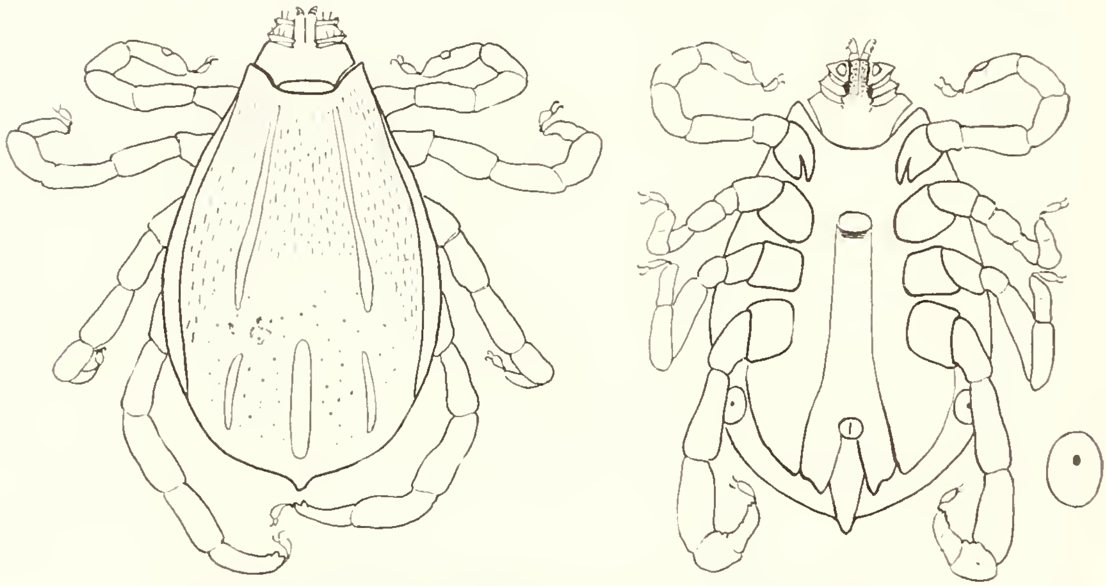

FIG. 79.—*Boophilus annulatus*, male, dorsal and ventral view.

absent or only faintly indicated; spiracles rounded or oval; the male is provided with adanal and accessory adanal shields (Fig. 79).

The adult female tick when engorged is greatly swollen. She drops to the ground to lay her eggs. After hatching, the young or "seed ticks" climb on to a blade of grass or low foliage and attach themselves to passing cattle. From this on growth takes place on the same animal, the tick not leaving the host until fertilized by the male and ready to deposit eggs. This tick or closely allied species, perhaps only varieties, occurs in many parts of the world where Texas fever may also occur. For instance in Australia and the Philippine Islands there is a variety known as *Boophilus australis* Fuller.

In this genus the small size of the male as compared to the engorged female is very striking.

The Genus *Margaropus* was made for *winthemi* Karsch, a tick which has a preanal shield and the hind pair of legs in the male, greatly swollen.

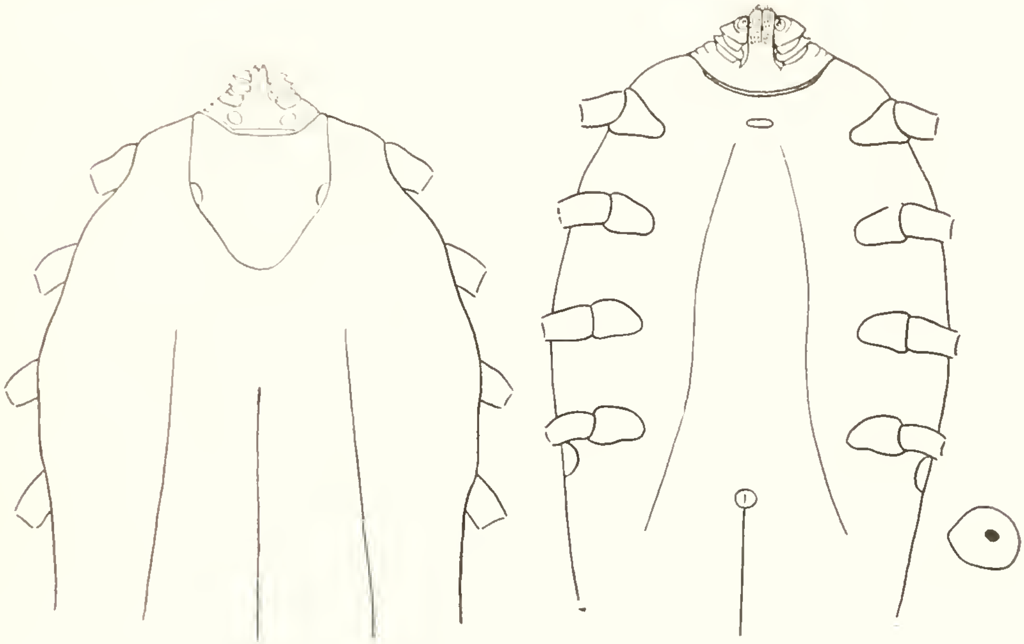

FIG. 80.—*Boophilus annulatus*, female, dorsal and ventral view.

Genus Haemaphysalis Koch 1844

This genus is characterized by being inornate and without eyes; festoons are present; the palpi are usually short and conical, with the base of the second joint projecting outwardly beyond the basis capituli; the basis capituli is rectangular dorsally; there is a dorsal process on the first trochanter and the ventral surface of the male is without plates or shields. (Fig. 81.)

Only a few species have been described from the United States of which *Haemaphysalis leporis palustris* (Fig. 81) is common on rabbits and widely distributed. *H. chordeilis* Packard has been taken from birds. *H. expositicius* has been found on cattle in Canada. The latter is an imported European tick. *Haemaphysalis leachi* Audouin is a South African dog tick and is a spreader of canine piroplasmosis. *H. punctata* is reported as causing fatal paralysis in a child in Australia.

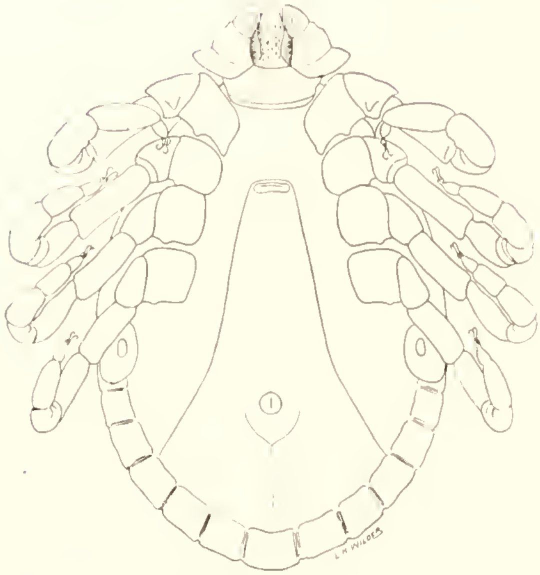

FIG. 81.—*Haemaphysalis leporis-palustris*, male, ventral view.

Genus Dermacentor Koch 1844

This genus is characterized by being usually ornate and with eyes and festoons present; the palpi are rather short and broad and the

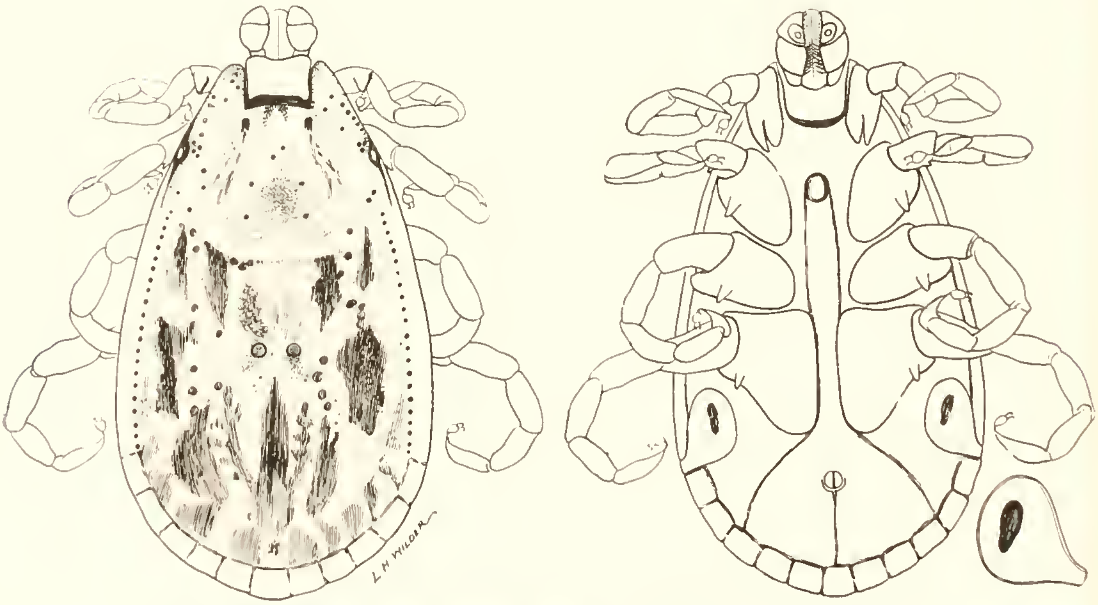

FIG. 82.—*Dermacentor andersoni*, male, dorsal and ventral view.

basis capituli is rectangular; coxa IV is much the largest; there are no ventral plates or shields. (Figs. 82, 83.)

There are some ten species reported from the United States. *Dermacentor variabilis* Say (*electus* Koch) is the common "dog" tick or "wood" tick of the Eastern States. On the Pacific Coast the com-

mon "dog" tick is *Dermacentor occidentalis* Neumann. Both of these ticks may be found on other animals and on man.

Dermacentor andersoni Stiles (Figs. 82, 83) is the tick of the Bitter Root Valley, Montana, and the North West and is the carrier

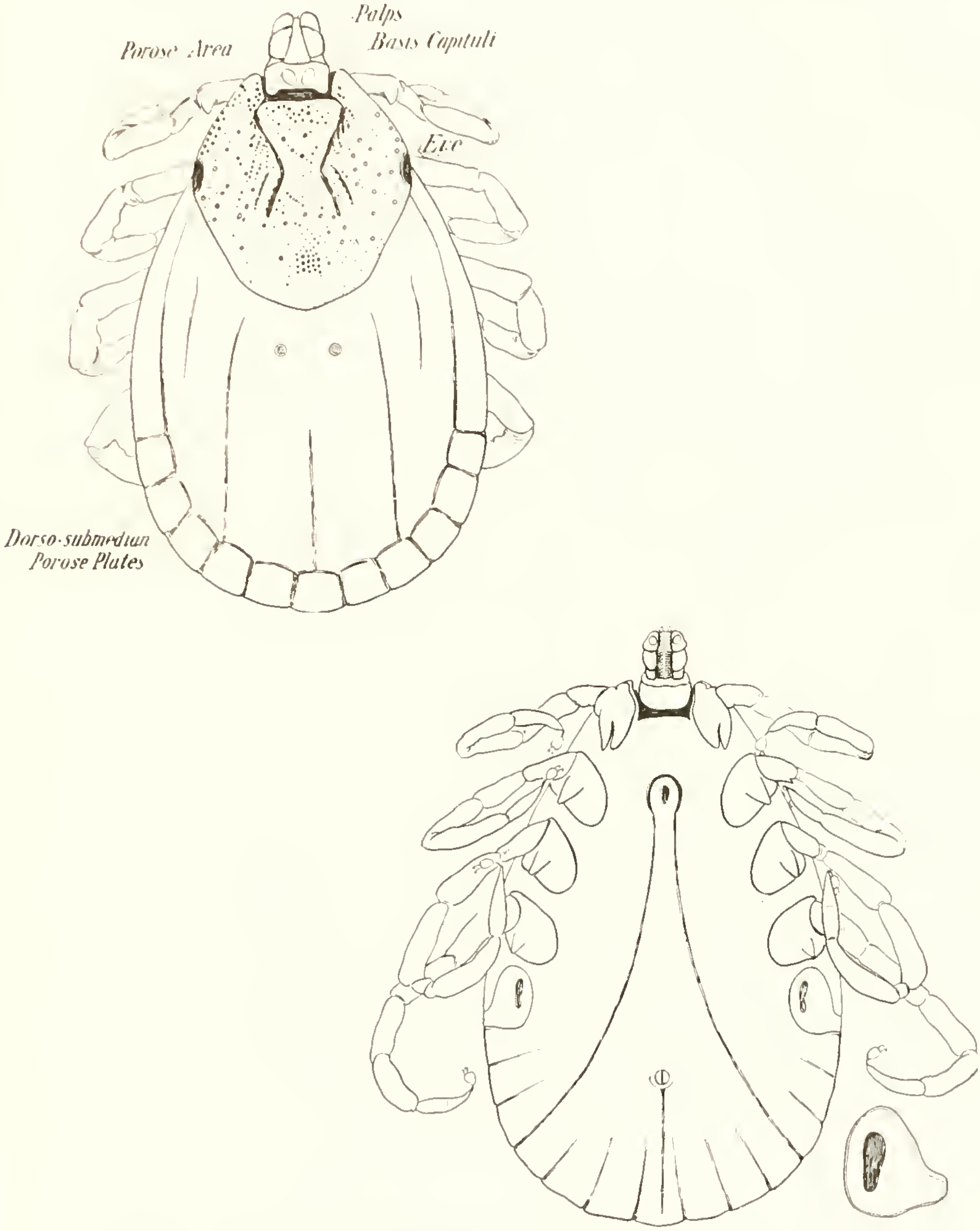

FIG. 83.—*Dermacentor andersoni*, female, dorsal and ventral view.

of Rocky Mountain spotted fever. (Chap. XXXVI.) This tick in all of its, stages feeds upon the blood of various warm blooded animals both domestic and wild. It will bite man. It has been taken from dogs, cattle, horses, swine, sheep, deer, mountain goats, bears, bad-

gers, coyotes, squirrels, chipmunks, rabbits, weasels, martens, porcupines and field mice. Larval and nymphal stages are only found on small mammals, adults on larger animals. Mating takes place on the host. When engorged the female drops to the ground and in about two weeks egg laying begins. Several thousand eggs may be deposited after which the tick shrivels and dies.

Under favorable conditions—summer temperature, out of direct sunlight—the eggs develop in from 30 to 50 days into larval or "seed" ticks, with but six legs. Colder weather may delay hatching for several months. The larva is very small at first, pale and soft but soon develops a hard, brown integument. The larva climbs upon a blade of grass or a twig and waits for a warm blooded animal to pass by. Once attached it becomes fully engorged in from three to five days. It then drops to the ground, becomes dormant for a period of from two to eight weeks and then moults into the eight-legged nymph. Many ticks never succeed in obtaining a host and perish for want of food.

The nymph again waits for a host on which to feed, upon which it remains for a period varying from four to eight days. It then drops off, remaining active for two to four weeks depending upon the temperature, then becomes quiescent and finally undergoes a last moulting, the fully formed adult emerging from the nymphal skin. The interval elapsing between larva and adult may be long—perhaps four or five years.

The adult then attaches itself to a warm blooded animal and the life cycle starts anew. One female produces but one brood. Ticks in all stages of development hibernate during the winter. Extremely low temperatures—30 or 40 degrees Fahrenheit below zero—will not kill them, nor will such temperatures destroy the virus of Rocky Mountain spotted fever in the body of an infected tick.

D. andersoni is the common wood tick of the Bitter Root Valley and is closely related to *D. venustus* of Texas and *D. occidentalis* of California.

Genus Rhipicentor Nuttall and Warburton 1907

In this genus eyes and festoons are present but there is no ornamentation; the palpi are short and the basis capituli is hexagonal dorsally having prominent lateral angles; coxa IV is much the largest; there are no ventral plates or shields; the male resembles *Dermacentor* ventrally and *Rhipicephalus* dorsally.

This genus is not reported from America.

Genus Rhipicephalus Koch 1844

In this genus eyes and festoons are present; there is usually no ornamentation; the palpi are short and the basis capituli is hexagonal

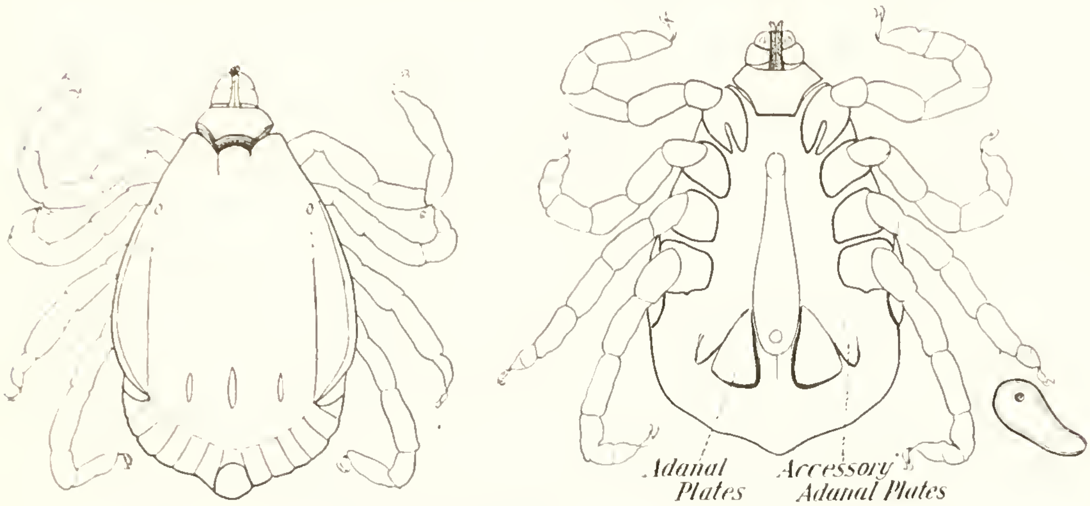

FIG. 84.—*Rhipicephalus sanguineus*, male, dorsal and ventral view.

dorsally with lateral angles more or less prominent; the male is provided with ventral shields and may show a caudal protrusion when replete. (Figs. 84, 85.)

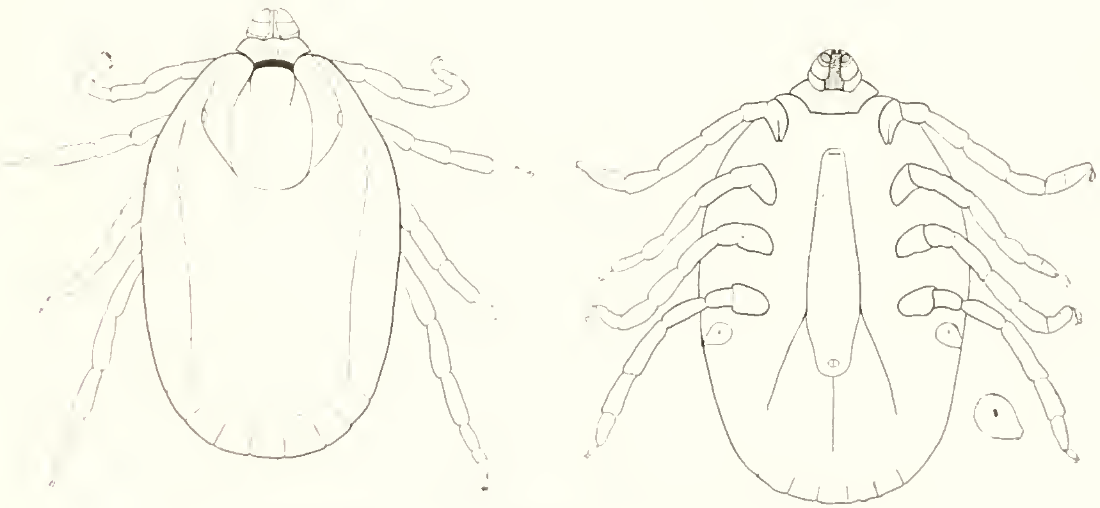

FIG. 85.—*Rhipicephalus sanguineus*, female, dorsal and ventral view.

Rhipicephalus sanguineus Latreille (Figs. 84, 85), the type species, is a widely distributed species now more or less common in the Southern United States. It is a dog tick but may occur on other hosts. It is the only member of the genus found in the United States.

This tick is responsible for the transmission of *Piroplasma canis* and *Haemogregarina canis*. In the first instance the parasite is acquired by the adult tick and is transmitted in the nymphal and larval stages. Little is known as to how the tick transmits *H. canis*.

Genus Hyalomma Koch 1844

In this genus ornamentation may be absent or present; eyes are present within the scutal margin and there are usually festoons; the palpi are long and the basis capituli subtriangular dorsally; the male is provided with shields ventrally and has two posterior abdominal protrusions capped by chitinous points; the female is more like Amblyomma.

This genus has not been reported from America.

Genus Amblyomma Koch 1844

This genus is usually ornate, with eyes marginal and with festoons; the palpi are long especially the second article; the basis capi-

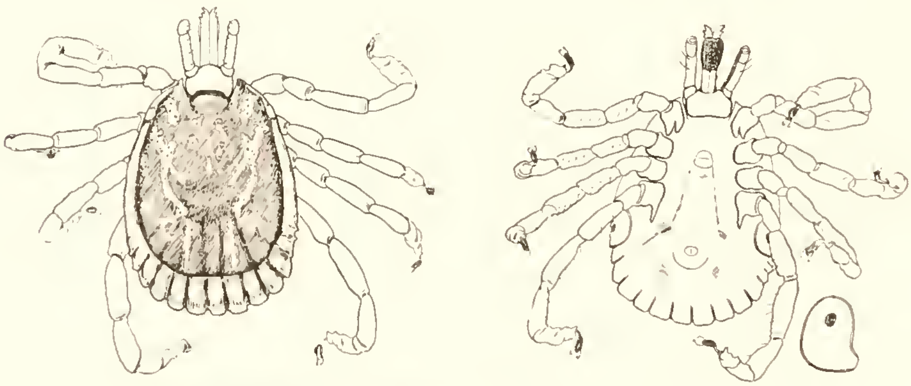

FIG. 86.—*Amblyomma cajennense*, male, dorsal and ventral view.

tuli is of variable form; the male has no ventral shields although there may be small ventral plaques close to the festoons. (Figs. 86, 87.)

The subgenus Aponomma differs from typical Amblyomma in that the eyes are absent or poorly developed and the body is frequently broad. This subgenus occurs on Reptilia.

There are many species of *Amblyomma* a number coming from Tropical and Subtropical America. The "lone star" tick, *Amblyomma americanum* Linn., is more or less common on cattle in the Southern States especially Texas and Louisiana. The female has a single bright, silvery spot at the tip of the scutum. The male which

is much smaller has several bright, silvery spots on its brownish scutum.

Amblyomma cajennense Fabricius (Figs. 86, 87) is a common tick of tropical America and extends up into Texas. The scutum in both sexes is yellowish with irregular silvery streaks and marks. A few other species are, *Amblyomma tuberculatum* from Florida from tortoise (gopher); *A. maculatum* is more or less common in certain localities on the Gulf Coast. Unlike others of the genus this tick has but one prominent spine on the fore coxae, others have two.

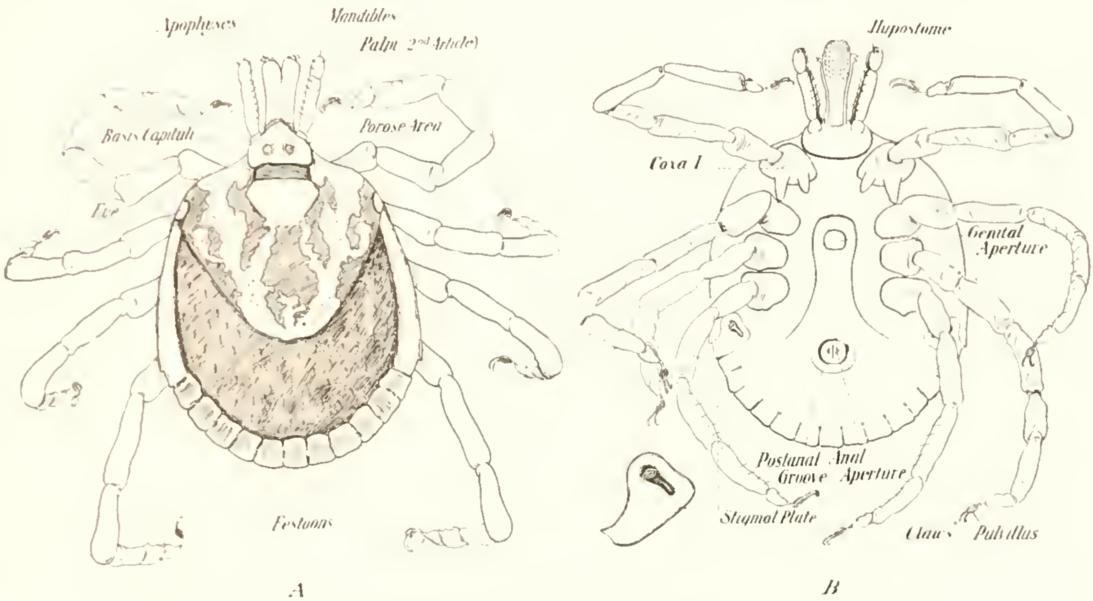

Fig. 87. *Amblyomma cajennense*, female, dorsal and ventral view.

A. hebraeum Koch disseminates heart water fever among sheep and calves in South Africa.

Key to a Few Species of American Amblyomma (After Banks)

1. Coxa I with but one spine, metatarsi (except I) with two thickened spurs at tip; second joint of palpus not twice as long as third; porose areas elongate; shield brown, with silvery marks. . . . . *maculatum*
   Coxa I with two spines; metatarsi without stout spurs at tip; only slender hairs. 2
2. Projections of coxa I blunt and short; porose areas elongate; second joint of palpus not twice as long as third; coxa IV of male with only a tubercle behind; large species. . . . . *tuberculatum*
   Projections of coxa I longer, and at least one of them sharp pointed; second joint of palpus twice as long as third; coxa IV of male with a long spine; smaller species. 3

3. Porose areas nearly circular; shield of both sexes pale and yellowish, with some silvery streaks and marks, and some reddish spots; shield of female as broad as long. . . . . *cajennense*
   Porose areas elongate; shield brown, in female with an apical silvery mark, in male with two small apical and two or four other silvery spots; shield of female longer than broad. . . . . *americanum*

CHAPTER XXI

SUPERFAMILY EUPODOIDEA

FAMILY EUPODIDAE

These mites are small, soft bodied and move rapidly. They live mostly on the ground but some are found on the leaves of trees. They like cold, damp places and are common in high altitudes and are frequently found in caves. Many are predaceous, feeding on other mites and small insects; some are found on snails and occasionally on insects. One, *Tydeus molestus* Moniez has been reported as attacking man.

FAMILY BDELLIDAE

These are the "snout mites." They are predaceous feeding on other mites and small insects. They are most common in cold countries and prefer a cold, damp environment. One species *Bdella cardinalis* Banks has been taken from *Rattus norvegicus* in New York City. They do not suck blood and were probably on the rats accidentally or to prey upon their ectoparasites.

Superfamily Trombidioidea

FAMILY CHYLETIDAE

These are very small mites, typically with large palpi attached to a distinct beak. They are predaceous and some are parasitic. They may be found on birds, insects or mammals where they are present to feed on other mites. Some live in the quills of birds or in the hair follicles where they form tumors.

One genus, *Myobia,* is based on a species, *Myobia musculi,* from the house mouse, *Mus musculus.* All legs are short and thick but the first pair is particularly heavy and adapted to grasping a hair. Other species have been reported from rodents and bats.

FAMILY TETRANYCHIDAE

These include the familiar "red spiders" so destructive to cultivated plants. Many of them can spin a thread hence the common

name "spinning mites" is frequently applied to them. They feed on the living plant sucking the juice from the leaves. They are found on cotton, alfalfa, clover, orange, lemon and other trees, moss, green house and out-door cultivated plants etc. When clover is grown close to the house, it is reported that the clover mite (*Bryobia praetiosa* Koch), upon the approach of cold weather, may enter for shelter and greatly annoy the occupants.

FAMILY TROMBIDIIDAE

These are the "harvest mites." Most of the species are red or reddish in color. The six legged larvae are parasitic on insects and mammals including man. However it is probable that man serves only as an accidental host. Nymphs and adults probably live chiefly on small insects.

The family is characterized by the body having two distinct divisions, the anterior or cephalothorax bearing the two anterior pairs of legs, the palpi, the mouth parts and the eyes of which there are two on each side; the posterior portion or abdomen bearing the two posterior pairs of legs. The mandibles are provided with a distinct jaw (hence *chelate*) or curved spine-like process; the palpi are five jointed, prominent, often swollen in the middle, the next to the last joint terminating in one or two claws, the last joint acting as a thumb to the preceding joint; the body is clothed with bristles or feathered hairs. A dorsal groove along the median line of the cephalothorax may be present. This is called the *crista* or *crista metopica*. Eggs are laid and hatched in or on the ground and it is likely that except when on a host, the larval mite spends its existence on the ground, not climbing up on vegetation as do the ticks.

The harvest mites are wide spread and in the larval stage cause much annoyance to man by reason of the reaction following the bite. One, the Kedani mite of Japan, is responsible for the transmission of Tsutsugamushi or Japanese River fever. (Chap. XXXVII.) This mite, *Trombicula akamushi*, in its life history does not differ materially from other mites of its kind. The larva is very small and bright red or orange in color. The nymphal and adult forms do not bite but live on vegetable juices. Blood is obtained by the larvae usually from the small rodents of the locality, especially the field mouse (*Arvicola hatanedzumi*) on which they congregate about the ears. The larva develops into an octopod nymph which after one, or perhaps more moults becomes the fully formed acarine which may be

found under fallen leaves or decayed vegetable matter in areas which have been subjected to inundation.

There are at least three European forms of chiggers as well as species in other parts of the world. According to Ewing the chigger of the United States, *Trombicula irritans*, is the same as the Mexican chigger, *Trombicula tlalzahuatl* Murray. It is widely distributed in the United States from Long Island to Central Mexico and from the Atlantic Coast to the Rocky Mountains.

The chigger mites have been known for many years under the name of *Leptus*,—*Leptus autumnalis* in Europe and *Leptus irritans* or *americanus* in the United States. This was before their proper place in the acarine world was recognized.

The chigger of the house fly is *Trombidium muscarum* Riley. At times many of the flies are seen to have these small red mites attached to them. *Euthrombidium trigonum* is more or less common on locusts and grasshoppers or other Orthroptera both in the United States and parts of Europe.

Key to Some of the Genera in the Family Trombidiidae (Adults) (After Banks)

1. No crista metopica . . . . *Trombella*
   Crista metopica present 2
2. Sides of body with projections . . . . *Chyzeria*
   Body without projections 3
3. Claws with a pulvillus; eyes pedunculate; one claw at tip of palpus. *Allothrombidium*
   No pulvilli 4
4. No eyes 5
   Eyes present 6
5. Crista enlarged near middle . . . . *Typhlothrombidium*
   Crista enlarged at end . . . . *Trombicula*
6. Eyes sessile; palpus with two claws at tip 7
   Eyes pedunculate 10
7. Crista enlarged but once 8
   Crista enlarged twice 9
8. Enlarged only at end; abdomen higher than the cephalothorax. *Microthrombidium*
   Enlarged only near middle; abdomen and cephalothorax of same height. *Tanaupodus*
9. Crista enlarged at middle and at end . . . . *Euthrombidium*
   Crista enlarged twice near the middle . . . . *Diplothrombidium*
10. Crista enlarged near middle 11
    Crista enlarged near end 12
11. Eyes long pedunculate; no teeth at the base of the palpal claw. *Dinothrombidium*

Eyes short pedunculate; teeth at the base of the palpal claw. *Podothrombidium*

12. Crista enlarged near anterior end; eyes long pedunculate; no teeth near palpal claw; legs rather short........................*Trombidium*
Crista enlarged near posterior end; eyes short pedunculate; teeth near palpal claw; legs very long.........................*Johnstoniana*

Superfamily Parasitoidea (Gamasoidea)

This superfamily has been divided into three families of which Parasitidae is the best known and contains some familiar examples.

FAMILY PARASITIDAE

Many of these mites are parasitic on insects and vertebrates. Eyes are absent; the mouth parts are retractile; the mandibles are either clawed with the fingers of the claw toothed, or they are adapted to piercing; an epistome and a hypostome (not provided with teeth as in the ticks) may be present, together with a long fleshy part, the lingula, between the points of the bifid hypostome; the palpi are usually five-jointed; the legs six-jointed; the venter is provided with plates or shields; the breathing spiracle is located on each side above and slightly in front of coxa IV (Metastigmatic) and is surrounded by a chitinous ring, the peritreme, which extends forward for a varying distance in a more or less sinuous line.

Banks divides the Family Parasitidæ into five subfamilies as follows:

1. The spiracle and peritreme (nearly or quite) on the dorsum; legs short and very bristly; all with large caruncles.....................Spinturnicinae
Spiracles and peritremes ventral.................................2
2. No shield or chitinous surface about the anus; parasitic within mammals. Halarachinae
A shield or chitinous surface about anus; not parasitic in mammals..........3
3. First pair of legs inserted within the same body opening (camerostome) as the oral tube; dorsum of body projects beyond the camerostome; genital apertures in the sternal plate; often occurring on insects.....Uropodinae
First pair of legs at one side of the mouth opening; dorsal surface of body does not project in front of the camerostome; male genital opening usually on the anterior margin of the sternal plate (sometimes in the middle)......4
4. Jaws of mandibles without teeth, often stylate or needle-like; parasitic on birds, mammals, or reptiles; tarsus 1 with claws or caruncles; leg II of male never with processes; anus in female usually at the front end of the anal shield; all the chitinous shields rather weak, and often not evident. Dermanyssinae
Jaws of mandibles toothed; rarely stylate or needle-like; usually not found on animals, except insects.... .. ..Parasitinae

Of the above, the Spinturnicinae are mostly parasitic on bats, some on sparrows, swallows, the domestic fowl and other birds. The Halarachninae include but two genera, *Halarachne* which has been found in the bronchial passage of seals, and *Pneumonyssus*, which has been found in the lungs of monkeys.

The Uropodinae are frequently found on insects. They are not necessarily parasitic but often use the insect as a means of transportation. They live in decayed wood, humus, manure etc. and probably feed in part at least on bacteria and fungi.

The Dermanyssinae contains members some of which are well known. Ewing regards the Dermanyssid mites as constituting a family which is characterized as follows;—"Mouth parts adapted for piercing, the chelicerae being either devoid of one or both of the chelae or of all true teeth, but however, recurved "hold-fast" hook-like structures are sometimes present. Integument somewhat leathery and distensible, but covered to a large degree by one or more dorsal shields and one or more ventral plates. Each tracheal trunk opening through a peritreme situated on the side of the body. Sexual dimorphism evident and at times marked. Parasitic in habits and on vertebrates."

Ewing separates them as follows:

Key to the Subfamilies and Genera of Dermanyssidae (Ewing, 1922)*

a¹. Chelicerae adapted for both piercing and attachment, being provided with recurved barbs or hooks.

b¹. Both chelae of chelicera present, the fixed one harpoon-like with a single recurved barb and the movable one falciform; hypostome without recurved hooks............................Subfamily Entonyssinae

Containing but one genus..........................*Entonyssus* Ewing

b². One chela of chelicera lost, the remaining one provided with several recurved hooks; hypostome with a pair of recurved hooks.

Subfamily Ixodorynchinae

Containing but one genus......................*Ixodorhynchus* Ewing

a². Chelicerae provided only for piercing, hence without hooks or barbs.

b¹. Chelicerae shear-like in both sexes, never needlelike.

Subfamily Liponyssinae

c¹. Body of both sexes entirely covered above by dorsal shield, sternal plate of female large and reaching to the third coxae.

Tetragonyssus Ewing

c². Body not entirely covered above by dorsal shield in either sex.

d¹. Female with a divided dorsal shield.

*The Dermanyssid Mites of North America by H. E. Ewing. No. 2459 Proceedings of the U. S. National Museum, Vol. 62, Art. 13, 1922.

e[1]. Posterior dorsal shield large, covering much of the abdomen above; first segment of palpus of female with a horn-like process. *Ceratonyssus* Ewing

e[2]. Posterior shield minute; sternal plate with only four setae; first segment of palpus of female without any horn-like process. *Serpenticola* Ewing

d[2]. Dorsal shield of female entire.

e[1]. Legs stout; tibia I and II less than one and one half times as long as broad; femora I and II spined above. . *Ichoronyssus* Kolenati

e[2]. Legs not so stout, especially the first and second pairs, tibia I more than one and one half times as long as broad; femora I and II not spined above.

f[1]. Body of female with a constriction and incomplete transverse groove behind the insertion of the last pair of legs. *Leiognathus* Canestrini

f[2]. Body of female without constriction and incomplete transverse groove. . . . . *Liponyssus* Kolenati

b[2]. In the female, chelicerae needle-like; in the male; variously modified but always with both arms present. . . . . Subfamily Dermanyssinae

c[1]. Dorsal shield of female entire; anus situated in posterior part of anal plate. . . . . *Dermanyssus* Dugés

c[2]. Dorsal shield of female divided; anus situated centrally in anal plate. *Allodermanyssus* Ewing

Of the above genera, *Liponyssus* and *Dermanyssus* are perhaps of the most interest to the medical entomologist as they contain a common rat mite, *Liponyssus bacoti* Hirst, and a common chicken mite, *Dermanyssus gallinae* Redi, both of which have been known to bite man and may be of great annoyance. The peritreme of *D. gallinae* is long and sinuous and extends beyond the second coxae.

The subfamily Parasitinae contains many genera, some of which are parasitic on insects and some on mammals. Many of them although predacious, feeding on other mites or small insects, do not attach themselves to the host but live in moist soil, fallen leaves, refuse, etc.

The genus *Laelaps* is important because it occurs on small mammals and in their nests. In this genus there is a stout bristle at the apex of the anal plate and one on each of the coxae. *Laelaps echidninus* Berlese. (Fig. 88) is the common mite of rats in all parts of the world. Three other species have been taken from rats, *Laelaps agilis*, *L. stabularius*, and *L. hawaiiensis*. They are not known to bite man. The latter is a small species. *L. stabularius* may cause a puritus without skin lesions.

Raillietia auris Leidy lives in the ears of cattle.

The genus *Parasitus* (formerly and better known as *Gamasus*) includes numerous species which are not parasitic on vertebrates and not often on insects. They are found among fallen leaves or in refuse or debris and a few inhabit sea beaches.

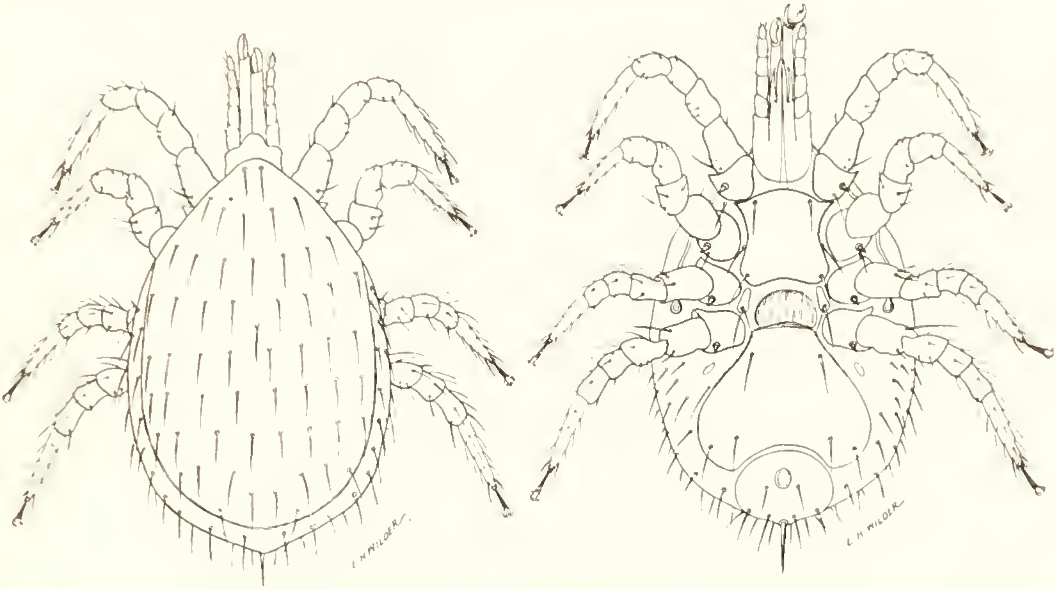

FIG. 88.—*Laelaps echidninus*, dorsal and ventral view.

Superfamily Oribatoidea

These mites can be distinguished by the presence of a hair arising from a pore near the corner of the cephalothorax on each side. They are not parasitic on animal or vegetable life and are therefore of little economic importance. They feed on vegetable matter but do no harm.

Superfamily Sarcoptoidea

FAMILY TARSONOMIDAE

These mites are of great economic importance as many of them are destructive to vegetable life, tea, rice, grasses, pineapple, fruit trees, green house plants, etc. One, *Pediculoides ventricosus*, (Fig. 89) infests grain for the purpose of attacking insects which may be upon it. When feeding on injurious insects its presence is beneficial. On the skin of man it produces a dermatitis, "straw itch" or "grain itch" which may be extremely annoying to those working in the fields or sleeping on fresh straw mattresses and may occur in epidemic form. *Pediculoides* brings forth adult offspring.

The Tarsonomid mites usually can be distinguished by the presence of a small organ bulbous at the end, arising between legs I and II. (Fig. 89 A.) A capitulum is present; the chelicerae are slender and needle-like; the palpi are minute; the posterior legs are remote from the anterior.

Ewing gives them rank of a superfamily and proposes the following key to the families and genera.

FIG. 89.—*Pediculoides ventricosis*, female, dorsal view.

The Classification of the Families and Genera of the Tarsonemoidea (Ewing, 1922)*

A. Both sexes provided with four pairs of functional legs.

B. Females with elongate bodies; capitulum and first two pairs of legs not covered by any projecting cephalothoracic shield.

C. Posterior legs of female each ending in a pair of claws and caruncle. Species usually ovoviviparous. . . . . Pediculoididae

D. Female with a large capitulum, showing a rostrum and rudimentary palpi; segments of abdomen distinct.

E. Larval stage represented by octopod deutovum stage; gravid female with only the tip of abdominal wall swollen.

Pediculoides Tar-tpz.

EE. Larval stage normal; most of the dorsal wall of abdomen distended in gravid female. . . . . *Pediculopsis* Reuter

DD. Female with capitulum reduced to a cephalic papilla, and abdomen indistinctly segmented . . . . *Pigmeophorus* Kram.

* Canadian Entomologist, May, 1922.

CC. Posterior legs of female devoid of claws and caruncle. Species oviparous. . . . . Tarsonemidae

D. Female with pseudostigmatic organs and very slender posterior pair of legs, which in the male are somewhat enlarged.
Tarsonemus C. & F.

DD. Female without pseudostigmatic organs and with short, stumpy fourth pair of legs, which in the male are reduced.
Acarapis Hirst

BB. Females with subdiscoidal bodies; capitulum and first two pairs of legs covered by the projecting cephalothoracic shield. . Disparipedidae

C. Females with posterior legs each composed of five segments and provided with a pair of claws and caruncle

D. Anterior legs of female each provided with a claw.

E. Segments IV and V of leg IV of female exceedingly slender, cylindrical and subcapillary. . . . . *Imparipes* Berl.

EE. Segments IV and V of leg IV of female short, stout, and V never cylindrical. . . . . *Pygmodispus* Paoli

DD. Anterior legs of female clawless . . . . *Diversipes* Berl.

CC. Females with leg IV composed of four segments and without claws and caruncles.

D. Anterior legs of female each provided with a claw.
Disparipes Mich.

DD. Anterior legs of female clawless. . . . . *Variatipes* Paoli

AA. Males hexapod; females in their final stage legless. . . . . Podapolipidae

Contains the singular, degenerate genus. . . . . *Podapolipus* Rov. & Gr.

FAMILY TYROGLYPHIDAE

These mites are injurious to food stuffs, roots and bulbs. In the hypopial stage they may attach themselves to insects, or even small mammals, in order to be transported from one place to another more suitable locality. A species which was described by Banks as *Histiotoma tarsalis* lives in the nests of rats and is carried around as a hypopus by the rat flea.

Glyciphagus domesticus (Fig. 90) infests sugar and is a cause of grocer's itch. In this genus the anal and genital openings are large and some of the hairs of the body are feathered. *Tyroglyphus farinae* is also a wide spread species most commonly found in flour and grain. *Carpoglyphus passularum* infests dried fruits. A number of species are injurious to roots and bulbs.

The family **Canestriniidae** includes a few very small mites parasitic on insects especially beetles.

The family **Analgesidae** are the bird mites occurring exclusively on birds and feeding on the epidermal scales and feathers. Their presence is apparently not harmful.

The family **Listrophoridae** are the "hair clasping" mites, living upon small mammals. They are adapted to clasping a hair either by the last tarsal joint or the under lip. They cling to and feed on the hairs.

FIG. 90.—*Glyciphagus domesticus.*

FAMILY SARCOPTIDAE

These are the "itch mites." They are permanent parasites in or on the skin of man, animals and birds, producing a condition known as acariasis.

They are very small in size, with the surface of the body striated transversely and provided with a few bristles some of them short and strong; the palpi are small and three-jointed; the mandibles are chelate; the beak is prominent; the male may have a pair of suckers near the tip of the abdomen; the legs are short and stout and terminate in a claw and a long pulvillus, or there may be only a long bristle.

Key to the Sarcoptidae (After Banks)

1. Anal opening on the dorsum 2
   Anal opening below 3
2. On small mammals, not bats; third pair of legs in male without apical suckers. *Notoedres*
   On bats; third legs in male with suckers .... *Prosopodectes*

3. Pedicle of suckers jointed; mandibles styliform and serrate near tip. *Psoroptes*

Pedicle not jointed; mandibles chelate.................................4

4. No suckers to legs of females; parasitic on birds.............*Cnemidocoptes*

Suckers at least on legs I and II; parasitic on mammals....................5

5. Legs very short; in male the hind pair equal in size; body usually short. *Sarcoptes*

Legs more slender; in the male the third pair is much larger than the fourth; body more elongate.................................6

6. Female with suckers to fourth pair of legs.....................*Chorioptes*

Female without suckers to fourth legs...................................7

7. Hind part of male abdomen with two lobes.......................*Caparinia*

Hind part of male abdomen without lobes........................*Otodectes*

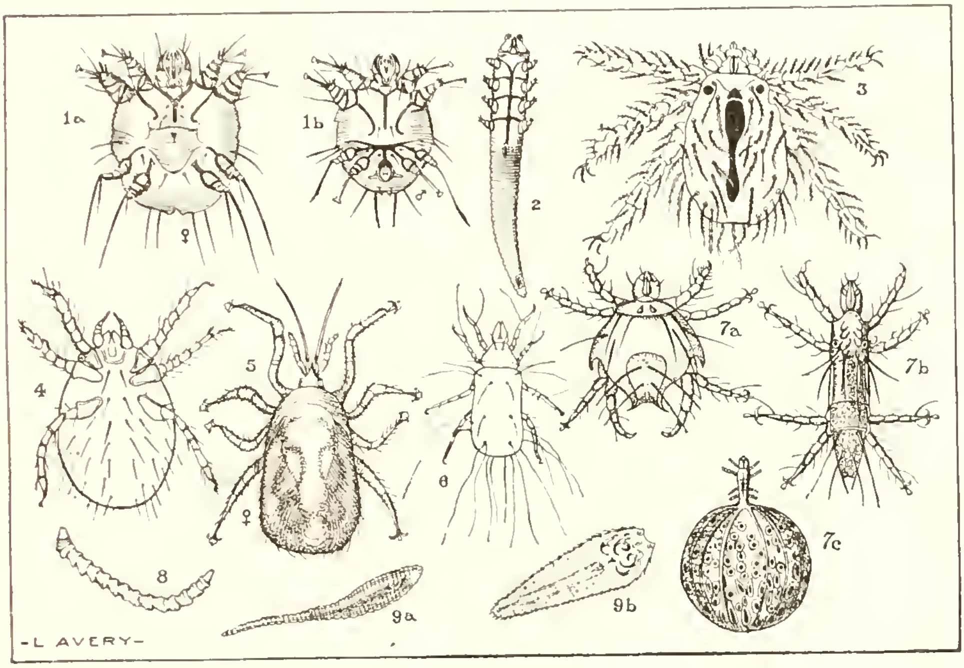

FIG. 91.—Arachnoidea exclusive of ticks. (1a) *Sarcoptes scabiei*, female; (1b) *S. scabiei*, male; (2) *Demodex folliculorum*; (3) *Trombicula akamushi*, hexapod larva (Kedani mite); (4) *Trombidium holosericeum* larva (Leptus); (5) *Dermanyssus gallinae*; (6) *Tyreglyphus longior*; (7a) *Pediculoides ventricosus*, male; (7b) *P. ventricosus*, young female; (7c) *P. ventricosus*, impregnated female; (8) *Porocephalus armillatus*; (9a) *Linguatula serrata*, female; (9b) *L. serrata*, larva. Note: Figure not drawn to scale. (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology," 7th. Edition.)

Sarcoptes scabiei De Geer is the itch mite of man. The female burrows under the skin, usually in the regions about and between the fingers, hands, wrists, axillary folds, lower abdomen, genital and anal regions. She lays her eggs in the burrow as she progresses, until finally she has deposited from 10 to 40 eggs extending along the burrow and interspersed with fecal matter and debris. The young mite like other acarines is three-legged. About four moultings

occur before the adult stage is reached. After mating the adult female undergoes a final moulting and then starts a burrow of her own but before doing so may migrate to another host. The females die at the end of the burrow when oviposition has terminated. The condition is attended by great itching and if not arrested is followed by inflammation and pustule formation. The following is said to be a good remedy:

Alcohol and water equal parts. To each fluidounce add one dram of precipitated sulphur. Shake well before using. Apply freely to affected area three or four times a day. Sulphur ointment is a good remedy. Clothes and bedding should be sterilized.

Species of the genus *Sarcoptes* may also be found on domestic animals.

The genus *Notoedres* is the itch mite of cats, rabbits and rats. It is found usually about the ears, eyes, nose and lips. It differs from *Sarcoptes* in having the anal opening situated dorsally.

The "scab mite" of sheep is an itch mite which does not burrow. It is known as *Psoroptes communis* var. *ovis*. It causes the formation of papules which become vesicles and finally pustules. These coalesce and in drying produce a yellowish, greasy, scaly layer under and around the edges of which the mites may be found. As the disease progresses this layer becomes thicker and more widespread gradually healing in the middle. The wool has a characteristic rough look and in places is stuck together in masses. Regions where the wool is thickest and longest, especially along the back, neck, flanks and rump are favorite sites for the mite to attack. Dipping is the proper treatment. Tobacco dip, sulphur and lime, arsenical dips, 8 per cent kerosene emulsion, are good. All should be applied thoroughly. Trees, fence posts, stable walls, etc. against which infested sheep have brushed, should be thoroughly white-washed.

The genus *Chorioptes* is another non-burrowing itch mite causing the so called "foot scab" of sheep. It may also attack the ears and neck. Horses, cattle and goats may be attacked by their own particular species of *Chorioptes*. The condition is not so serious as that produced by *Psoroptes* and is more easily cured.

The itch mites of poultry and other birds belong to the genus *Cnemidocoptes*. *C. mutans* is the itch mite of fowls producing what is known as "scaly leg." *C. gallinae* is found at the base of the feathers where it burrows.

FAMILY CYTOLEICHIDAE

These are also mites of fowls. *Laminosioptes* occurs on or in the skin where it produces a calcareous cyst. *Cytoleichus* is found most commonly in the air passages. Species have been taken from turkeys.

Superfamily Demodicoidea

The family Eriophydae are plant feeders, many of them producing galls or other deformations on the leaves and twigs of plants.

The family Demodicidae has but one genus, *Demodex*, which lives in the sebaceous glands and hair follicles of man and other animals.

CHAPTER XXII

RODENTS OR GNAWERS

VERTEBRATA. CLASS MAMMALIA. ORDER GLIRES

The following rodents have been found naturally plague infected:

Family Muridae (rats and mice)				Family Sciuridae (squirrels and marmots		Family Leporidae (hares and rabbits)	Family Caviidae
Sub-family Murinae (old world and domestic rats and mice) Genus *Rattus* *Rattus norvegicus* (gray or brown rat) *Rattus rattus* (black rat) *Rattus alexandrinus* (palm rat) *Rattus coucha* (multi-mammate rat) Genus *Arvicanthis* *Arvicanthis pumilio* (striped mouse) Genus *Gerbillus* *Gerbillus teterona* (gerbille) Genus *Mus* *Mus musculus* (house mouse)	Sub-family Cricetinae (American rats and mice) Genus *Oryzomys* *Oryzomys pulustris* (rice rat)	Sub-family Neotominae (wood rats) Genus *Neotoma* *Neotoma fuscipes* (brush rat)	Sub-family Microtinae (field rats and mice)	Sub-family Sciurinae (true squirrels and marmots) Genus *Citellus* *Citellus beecheyi* (California ground squirrel) Genus *Marmota* *Marmota bobac* (Tarbagan or Siberian marmot)	Sub-family Pteromyinea (flying squirrels)	Genus *Lepus* *Lepus europaeus* (English hare) Genus *Pryctolagus* *Pryctolagus cuniculus* (English wild rabbit)	Genus *Cavia* *Cavia cobaya* (guinea pig)

The scheme on preceding page indicates the position in zoological classification of the various rodents which have been found *naturally* infected with plague. Of these the domestic rats and mice and the California ground squirrel are of the greatest importance in the United States as harborers of plague bacilli.

Rodents have certain general characteristics which distinguish them from other orders in the class of mammals. They are usually small, furry, herbivorous animals with clawed digits and plantigrade feet. The most characteristic feature of the rodentia is their dentition. The canine teeth are absent and the incisors are elongated, curved and grown from permanent pulps. There are never more than two incisors in the lower jaw and there are usually two in the upper jaw. The fronts only are covered with enamel so that when in use these teeth wear away on the inner surface and are thus sharpened.

The members of the family Muridae, to which belong the rats and mice, using these terms in their broadest sense, have no premolars and the number of molars on each side of both jaws is three with the exception of one genus, Hydromys, in which the 3rd. molars are vestigial.

The Old world, true or domestic rats and mice (Murinae), may be distinguished from the American forms (Cricetinae) by the arrangement of the cusps on the unworn upper molars. In the Murinae they are arranged triserially, i.e., in three longitudinal rows while in the Cricetinae they are arranged biserially, i.e., in two longitudinal rows, one on the outer and one on the inner margin.

The common rats are characterized by narrow ungrooved incisors; three small, rooted molars; soft fur mixed with hairs, occasionally with spines; and a thumb provided with a short nail instead of a claw. The tail is ringed with overlapping scales and is naked or nearly so; the ears are large, the eyes are bright and prominent and the muzzle pointed. The difference between rats and mice is mainly one of size. Both have six foot pads. The last on the hind foot of rats being elongated while in the mice it is usually circular. Contrary to the belief held by some people mice are not young rats.

FAMILY MURIDAE

Sub-family Murinae

Rattus norvegicus (Gray, Sewer, Brown, Wharf or Norway Rat). This species probably came from Northern Asia, migrating into

Europe some time during the early part of the 18th Century. It has since spread to all parts of the world. It is larger and heavier than the following species, its muzzle is less pointed, its head is larger and thicker, its ears smaller and its tail is shorter than the head and body combined. In color it is grayish brown above with over hairs tipped in black, it is whitish below. Its average length including the tail is about 16.3 inches. The length of the hind foot is 1.5 to 1.8 inches (38–46 mm.). The female usually has twelve mammae, three pairs of pectoral and three pairs of inguinal.

The Norway rat is a powerful fighter and is ferocious among mammals of its own size and kind. It can burrow readily and lives within or near the ground, in burrows, sewers, basements, between cellar or basement walls, in or under lumber piles or wooden and concrete pavements and similar places favorable to hiding and breeding. It is especially attracted to places where food is abundant. It can gnaw its way through wood and plaster and is a good swimmer, but a poor climber. It is omnivorous. It can adapt itself to all sorts of climates but is more abundant in temperate regions. Rats breed the year round. The ratio of females to males is about 1.8 to 1. The period of gestation is three weeks. The average number to a litter is eight. Rats produce from three to five litters a year. The young females are capable of breeding when less than three months old. Rats are great travelers, migrating from place to place on foot as well as by ships and trains. The rat population, in a given community, is hard to estimate but it is not unlikely that usually there are at least as many as one rat to every person. Migration is prompted by varying conditions in the food supply and other conditions in the environment inimical to the propagation of the species.

Rattus rattus (Black, Ship, or Indian Rat).—The black rat is more slender in build than the gray rat. Its head is longer, its muzzle is more pointed, its ears are larger and wider and when laid forward reach to the middle of the eye or beyond. The tail is longer than the head and body combined. The fur is soft and thicker than that of the brown rat and the color is blue black above and black or slaty gray below (on the belly). Its average length is 14.9 inches. The length of the hind foot is from 1.3 inches to 1.5 inches, (33–37 mm.). The females of both the black rat and the roof rat (*alexandrinus*) have ten mammae, two pairs of pectoral and 3 pairs of inguinal. The black rat probably originated in Southern Asia,

migrating to Europe much earlier than the gray rat. It is the common rat in India, and is also found in many parts of the world including the United States, more especially in seaport towns to which it has been carried by ships. It is the rat common to ships. Like the palm rat it is a good climber and is usually trapped in the upper portions of the house. In fact it is rather distinctly urban in its habits and its residence in houses brings it in rather intimate contact with man. When introduced these rats are frequently killed off by the more ferocious gray rat before they have opportunity to multiply. It has been noticed that there is both a relative and absolute increase in the numbers of the black rat and the house mouse following a decrease in the number of gray rats.

Although the black rat is the common rat of India, the gray rat is more or less numerous in the seaport towns of that country especially at and near the waterfront, having been introduced by ships.

Rattus alexandrinus (Alexandrian, Palm or Roof Rat).—This species is very similar in size and characteristics to the black rat but its color is grayish brown above and white or yellowish white below. The Alexandrian rat may have been a native of Egypt but it is now found in many parts of the world, more especially in warmer countries. It is a good climber, and in tropical or semitropical countries lives in the Palm trees and is thus known as the palm rat. It is more rural in its habits than the black rat but also takes up its residence in houses. It is found in the United States, more especially in southern seaports.

In general, the breeding and feeding habits of the last two species are similar to those of the gray rat, but the number of young to a litter is smaller.

Albinos and spotted specimens of both the brown and black rat are not infrequently observed. The white rat of the bird store is an albino of *Rattus norvegicus*.

Mus musculus (The House Mouse).—The house mouse is cosmopolitan in its distribution. It resists extermination by the brown rat and other enemies because of its diminutive size which enables it to escape into places too small for its enemies to follow.

Diseases Other than Plague, Affecting Domestic Rats.—The following are some of the pathological conditions which have been reported as having been found in common domestic rats:

Rat leprosy	Rat scabies (*Notoedres alepis*)
Leptospira icterohaemorrhagiae (cause of Weil's disease)	Tularaemia
Trypanosomiasis (*Trypanosoma lewisi*)	Trichinosis (*Trichinella spiralis*)
Spiroschaudinnia morsusmuris (cause of rat bite fever)	*Spiroptera obtusa* (Found in stomach)
Hymenolepis diminuta	*Hymenolepis nana*
Hepaticola hepaticum (eggs and adults in liver)	*Gigantorhynchus moniliformis* (In small intestine. Intermediate host a beetle, *Blaps mucronata*)
Cysticercus fasciolaris (cat tapeworm, *Taenia crassicollis*) seen as cysts in the liver)	Pericardial effusion
Multiple abscess of the lung	Consolidation of the lung
Cirrhosis of the liver	Fatty degeneration of the liver
Hernia	Nephritis
Abscess of the kidney	Atrophy of the kidney
Vesicle calculi	Lipomas
Fibromas	Sarcomas
Adenomas	Carcinomas
Cystic adenomas	Fibro adenomas
Adeno-carcinomas	Epitheliomas
	Cancer of stomach due to *Gongylonema neoplasticum*

Natural Enemies of Rats.—Important natural enemies of the rat are larger hawks, owls, skunks, foxes, coyotes, weasles, minks, ferrets, certain breeds of cats and dogs, especially small, well trained Irish, Scotch and fox terriers, mongoose, alligators, and snakes.

Economic Considerations.—Aside from diseases such as bubonic plague and trichinosis which may be spread by rats, these vermin cause great damage to food stuffs of many kinds including grains, growing and stored, poultry, eggs, fruits, vegetables, etc. It has been estimated that the yearly losses from rats in Great Britian and Ireland are $73,000,000. It would probably not be far wrong to estimate the losses in the United States during a year at not less than $2.00 per capita, if one takes into consideration the amount of marketable food which they have either eaten or spoiled or which is otherwise lost through their depredations, as well as the destruction to property and the expense to which many persons are put to eradicate them. The great economic loss which rats cause to a community alone furnishes an excellent reason for their extermination.

Ectoparasites Which Have Been Found on the Genus Rattus and Mus in the Western Hemisphere.—The following ecto-parasites

have been reported from rats in the Western Hemisphere by various observers: many of these parasites have for their normal hosts animals other than rats, and sojourn on the rat is therefore purely accidental:

Order Siphonaptera

Tunga caecata Enderlein 1901 (Brazil, accidentally on *Rattus rattus*).

Echidnophaga gallinacea Westwood 1875 (California, New Orleans and New York City, a flea of fowls, accidentally on rats).

Pulex irritans Linn. 1758 (San Francisco, the human flea, cosmopolitan, accidentally on rats).

Xenopsylla cheopis Rothsch. 1903 (California, Galveston, New Orleans, New York, Boston, the common rat flea of tropical and subtropical countries).

Xenopsylla brasiliensis Baker 1904 (Brazil, a rat flea of Africa and India).

Ctenocephalus canis Curtis 1826 (Nearly cosmopolitan, the dog flea, accidentally on other hosts including rats).

Ctenocephalus felis Bouche 1855 (Cosmopolitan, the cat flea, accidentally on other hosts including rats).

Hoplopsyllus anomalus Baker 1904 (California, a squirrel flea, accidentally on rats).

Rhopalopsyllus gwyni Fox 1914 (From rats at a quarantine station, Georgia, a South American flea).

Rhoplopsyllus adelus J. & R. 1923 (Brazil, on *Rattus*).

Ceratophyllus fasciatus.Bosc. 1801 (Commonly found on rats in San Francisco, New York City and Boston, a European rat flea).

Ceratophyllus niger Fox 1908 (San Francisco, a flea of fowls, accidentally on rats).

Ceratophyllus acutus Baker 1904 (San Francisco, a squirrel flea, accidentally on rats).

Ceratophyllus londiniensis Rothsch. 1903 (San Francisco, a Mediterranean species).

Ceratophyllus anisus Rothsch. (San Francisco, accidentally on rats).

Ceratophyllus wagneri Baker 1904 (Idaho, on a house mouse, a flea of the white footed mouse).

Anomiopsylla nudatus Baker 1808 (Arizona, accidentally on *Rattus*).

Phalacropsylla paradisea J. & R. 1915 (Arizona, on *Rattus*, *Mus* and *Mephitis*).

Ctenophthalmus pseudagyrtes Baker (Boston, accidentally on rats).

Leptopsylla musculi Duges 1832 (Cosmopolitan, a flea of *Mus musculus* and *Rats*).

Order Anoplura

Polyplax spinulosa Burmeister (Cosmopolitan, the common rat louse).

Order Mallophaga

Philandesia foxi Ewing (New York City, accidentally on *Rattus norvegicus*)

Order Acarina

Boophilus annulatus Say (Dallas, Texas, on rat).
Laelaps echidninus Berlese (Widely distributed, a common rat mite).
Laelaps hawaiiensis Ewing (New York City, New Orleans).
Liponyssus bacoti Hirst (Widely distributed, on mice and rats).
Myobia musculi Schrank (On mice).
Notoedres alepis Railliet & Lucet (San Francisco, on *Rattus*).
Bdella cardinalis Banks (New York City, accidentally on rats).

FAMILY SCIURIDAE

(Squirrels and Marmots)

Plague is endemic among the ground squirrels of California, *Citellus beecheyi*. The characteristics of this squirrel are as follows: its upper front teeth are large and two in number, chisel shaped and separated from the grinding teeth by a wide space, grinding teeth at least 4 in each jaw; the fore feet are not modified for digging; their claws are normal; eyes are prominent; ears large and prominent; cheek pouches are present; the tail is well haired but not bushy and is more than two thirds the length of the body; the nail of the thumb is rudimentary; above, the color is mixed black and pale yellowish brown. It is terrestial in its habits, living in burrows in the ground. It breeds in February, March and April. The number of young to a litter averages 8; the number of males to females is 1 to 1.4. Its fleas are *Ceratophyllus acutus* Baker and *Hoplopsyllus anomalis* Baker, both of which feed readily on man's blood. The louse of this ground squirrel is *Linognathoides montanus* Osborne.

The Siberian marmot, *Marmota bobac* is related to the ground-hog or wood-chuck and also has some other relatives in the United States such as the ground squirrel. It is characterized as follows: its upper front teeth are two in number, chisel shaped, both large, and separated from the griding teeth by a wide space, grinding teeth at least 4 in each jaw; ears large; forefeet not modified for digging, their claws normal; the tail is short and less than one-half the length of the body, bushy and not flattened; the thumb nail is broad and flat; the fur is long, coarse and heavy; the skull is nearly straight causing the head to appear flat above; the color is uniform being yellowish brown above overlaid with black. It is terrestrial, living in burrows. The flea of this rodent is *Ceratophyllus silvantieri* (Wagner) which has been shown to bite man.

CHAPTER XXIII

A FEW NOTES ON TECHNIQUE

Collecting.—In collecting insects the medical entomolgist will be most interested in those found in, on or around animals or those which are found breeding in animal excrement; in those which bite or otherwise annoy man or are found in his habitation or which breed in human excrement, in carrion or other refuse, in food stuffs or in water or damp places.

In collecting diptera a net made of bobbinette of small mesh, with a handle, is necessary. It is well to rear the carrion breeders by taking some of the material on which the eggs or larvae are found and some of the earth beneath (or some sand or loose soil), place it in a shallow box covered by a frame to which is tacked mosquito wire screening and thus permit the process of development to proceed to the adult stage. For mosquitoes see page 247.

Lice and ticks should be collected directly from the animal or bird, mites from the animal or bird or their nests.

Fleas soon leave the host after it is dead. Therefore they should be collected from live animals or perhaps better still from the nests of animals or birds. The nest may be placed in a box with a piece of moist blotting paper in the top to prevent drying. The larvae will go on to development. Fleas may be obtained from the host by searching through the hairs and picking off with forceps or they may be stupefied with a tiny pledget of cotton on the end of a match stick moistened with chloroform. The animal itself may be placed in a jar and anesthetized. The fleas will then jump off and feeling the effects of the anesthetic may be readily picked up with a pair of small forceps. Combing with a fine-toothed comb is an excellent means of dislodging fleas.

In collecting parasitic insects the host should be accurately identified and noted on the label.

Killing.—For killing insects after capture, chloroform may be used, or potassium cyanide (a deadly poison). Some small lumps of the latter are placed in the bottom of a wide-mouth bottle, and dusted with dry plaster of Paris. A soft paste of plaster of Paris

is then added so as to cover the cyanide for a depth of about 5 mm. and allowed to dry. After drying the bottle should be tightly corked. When ready for use a few strips of blotting paper placed in the bottle will absorb moisture and prevent insects placed therein from being shaken around and becoming mutilated. All cyanide not used should be adequately disposed of by burying it deeply in the ground, away from all possible contact with children or domestic animals, as it is a deadly poison.

Chloroform is a useful killing agent but stiffens the muscles of the insect. It is quite volatile, but will last longer if prepared as follows: some elastic (rubber) bands should be soaked in the chloroform and then dropped into a wide-mouth bottle, and a piece of blotting paper pushed down over the rubber bands to hold them in place.

The chloroform may be used on a pledget of cotton held in place at the bottom of the bottle by a piece of blotting paper.

In the field, for small diptera, tobacco smoke may be used in the absence of a better killing agent.

If caught alive insects like lice and mites may be killed by immersion in water brought almost to the boiling point. This method tends to keep the legs spread apart. Larva may be killed in hot water before placing in the preservative.

Mounting.—Small diptera may be preserved in alcohol, or mounted on a slide in Canada balsam. As a general rule it is better to mount diptera on entomological pins thrust through the thorax dorso-ventrally a little to the right of the median line. Thirty-four mm. black insect pins Numbers 1 and 2 are handy sizes. Some prefer to mount insects on small triangular pieces of thin white cardboard or heavy white paper, about 8 mm. long. The entomological pin is thrust through the base of the triangle and the point of the triangle is fastened to the ventral surface of the insect by some adhesive, a good one being white shellac dissolved in 95% alcohol. This is a good method for small diptera; another is to use very small entomological pins (micro-pins). These are useful in mounting mosquitoes. The micro-pin is thrust through the thorax of the insect and its point is then inserted into a small piece of cork which in turn is pierced by the larger pin.

After the insect is mounted, the label, or labels, should be pushed up on the pin below the insect. The insect should never be pushed to the top of the pin and it and the labels should be evenly spaced. For this purpose a pinning block is useful.

Diptera should be pinned while fresh. They are easily broken when dry. If they have dried, they should be relaxed before handling. A relaxing chamber (moist chamber) may be improvised by placing moist blotting paper in a saucer which is then covered by another saucer. Or, a jar containing a layer of moist sand can be used. A piece of blotting paper under the cover will prevent condensed moisture from dripping on the specimens.

Fleas should be cleared and mounted on slides. The following technique may be used:

1. KOH 10% in water to dissolve the soft parts and to decolorize the chitin. The solution may be used cold or warmed over a water bath. Never use very hot or boiling KOH as it will distort the parts. In fact some authorities dispense with it altogether. If used it must not be allowed to act too long. The process must be watched. A flea can be completely decolorized by the caustic and this is highly undesirable.

2. Wash thoroughly in water to remove all of the caustic.

3. Dehydrate by running through the alcohols, 80% and 95% each about 15 minutes, and then in two changes of absolute alcohol.

4. Clear in Xylol or Oil of Cloves.

5. Mount in Canada balsam.

An excellent dehydrating and clearing agent is carbolic acid crystals dissolved in xylol to saturation. When this is used no absolute alcohol is necessary.

In dried specimens the soft parts have practically disappeared through dessication. If not mutilated such specimens make good mounts and the caustic need not be used. If a specimen is contracted it will expend if treated with H_2O_2 before preparing to mount.

With lice, best results are obtained if they are stained before mounting, as follows:

1. Treat until transparent with warm KOH (10%).

2. Wash thoroughly in water.

3. Stain with Acid fuchsin in water to which .008 HCl has been added. The specimen should be over stained.

4. Run through the alcohols rapidly. The alcohol decolorizes and therefore the process should be watched.

5. Clear in Xylol or one of the other clearing agents.

6. Mount in Canada balsam. Professor Herms uses weak Magenta red for staining lice. For removing small insects from

solutions or for pipetting off a solution to be replaced by another, a medicine dropper is useful.

Preservation. For preserving the pinned specimens a special entomological box (Schmitt box) should be obtained. It should be air-tight and light-tight, therefore it should have a well fitting cover. It should have a soft inner bottom made of cork or pith so that the pin carrying the insect can be easily pushed into it. Special pinning forceps may be obtained.

Certain beetles and mites are pests to a collection and completely destroy the specimens through their depredations. Therefore it is well to fumigate occasionally, placing the specimen box in a larger box and using carbon bisulphide. A repellant should also be kept in the specimen box. Naphthelene is a good one. The flakes may be tied in a small bag fastened to an inside corner of the box, or, a pin may be heated and thrust head-first into a naphthelene ball (moth ball). When cool the pin will be securely fixed in the naphthelene and can be pushed into the bottom of the box. Another method is to melt the naphthelene, then tilt the box slightly and pour the naphthelene into a corner or between the corners where the bottom joins the sides.

Shell vials may be used for storing specimens. The pin bearing the insect is thrust into the cork. The specimen should be allowed to dry before the cork is put in place as moisture condensing inside of the vial will favor the growth of moulds. The tip of the cork may be dipped in melted naphthelene.

Formaldehyde in a 4% solution (1 part of commercial formalin to 10 parts of water), is a good preservative for fly and mosquito larvae. It is also a good fixing agent for tissues.

To preserve such arthropods as fleas, lice, ticks, bed bugs etc., 70% alcohol is satisfactory. In this they may be kept indefinitely. A very small amount of glycerine added to each vial will prevent the too rapid evaporation of the alcohol. It will also prevent drying even after the alcohol has evaporated. Homoepathic vials make good containers.

All containers should be properly labeled with the name of the specimen, host, date of collection, locality, name or initials of collector and also the initials of the one who made the identification.

It is better to put the label inside of the vial with the specimen rather than to paste it on the outside. It should be written in

waterproof ink and immersed in alcohol before putting it in with the specimen. Ordinary lead pencil may be used but will fade.

Examination. A binocular microscope for entomological work is almost indispensable for the examination of flies, mosquitoes, ticks, etc., i.e., all insects that are not adapted to clearing and mounting on a slide. Even with insects like fleas much can be learned from the unmounted specimen by the use of a binocular microscope. A good light from above is essential. Artificial illumination and a good reflector or a focusing glass to direct light on the field to be examined should be available. In lieu of a binocular microscope, a dissecting microscope can be used. For field work a pocket magnifying glass should be carried. A half-inch lens is a useful size.

For holding ticks, fly larvae, etc., or insects mounted on pins, in any position desired for study under the microscope, plasticine or modeling clay are useful. Or, a cork stopper may be used where insects are mounted on pins.

Cleared specimens should be examined with the low power of a compound microscope, and with the light coming from below. A very bright light is not always desirable for this purpose. It should be regulated to suit conditions. For details a higher powered lens should be used.

When one has a long series of insects like fleas to examine it is not necessary to mount all of the specimens. Take them from the alcohol in which they are preserved, and, either cleared or uncleared arrange them on a slide and examine with the compound scope. Mount only those in which there is any doubt as to their identity.

Forwarding.— Diptera may be shipped in pill boxes. To prevent them from being shaken around in the box, small pieces of loosely crumpled tissue paper may be used. Never permit cotton to come in contact with an insect as the setae will become entangled in the fibres of the cotton, making it hard to separate them without mutilation.

Insects that can be preserved in alcohol should be shipped in Homeopathic vials well stoppered and surrounded by cotton.

In all cases a strong outside container should be used and if sent by mail the regulations of the Post Office Department should be followed.

Dissection and Staining. Mosquitoes.— For the internal organs, fresh specimens should be used. First take off the legs and wings,

place the mosquito on a glass slide and remove all debris. If the salivary glands and the alimentary tract of the same mosquito are required the former should be dissected out first.

The thorax should be steadied by a needle held in the left hand, then with another needle in the right hand, draw the head away from the thorax and into a drop of saline solution by a series of gentle pulls. The oesophagus and muscles will rupture and the glands with their ducts will be drawn out of the thorax together with some muscle fibres, fat body, nerve trunk and cervical tracheae. Cut the mass loose from the head. The glands may be identified by their highly refractile appearance and may then be separated from the other tissues.

To remove the alimentary canal, steady the thorax as above and then with a second needle gently crush between the last and next to last segments of the abdomen dorsally and ventrally. Draw the last segment away from the abdomen into a drop of salt solution by a series of slow steady pulls as before. The alimentary canal up to the oesophagus, and the reproductive system will be drawn out of the abdomen and can be dissected away from each other and from the tracheae which hold them in position. It may be necessary to cut the main tracheae before the organs are entirely free from the abdomen. The tracheae can be identified by their silvery appearance.

When the salivary glands of the same mosquito are not required, it is better to decapitate by cutting, not pulling, before attempting to take out the mid- and hind-gut. It is also better to wait until the stomach is partially empty, before killing.

Ticks.—To dissect a tick one should slit around the edge or cut away a thin slice of the integument from the edge, extending from the level of one coxa to the coxa on the opposite side. The tick should then be placed ventral side down and held by an entomological pin thrust through the side of the basis capituli. The paraffine trough devised by Christophers may be used. The tick being fastened, the dorsal flap is lifted and the lateral incisions carried up along the sides of the cephalo-thorax by a needle with a cutting edge. This flap is then slowly reflected back over the capitulum. The internal organs are then in view with the aorta uppermost. The various organs can then be separated, but great care is necessary. A medicine dropper may be used to wash away debris or material from a ruptured intestine which obscures the field.

The paraffin trough devised by Christophers is made by filling a glass dish like a Petri dish, with about one-half inch of a mixture of melted paraffine and lamp black which is then permitted to cool and harden. Specimens may be fastened to this with entomological pins.

Francis has had good dissection results by holding insects in place with a strip of surgeon's adhesive plaster fixed to a thin piece of wood.

Chitinous parts may be dissected apart in the clearing agent (Xylol or Oil of Cloves) but it must be remembered that Xylol and 95% or absolute alcohol tend to make chitin brittle.

In dissecting insects, practice alone makes perfect. This is especially true in the case of small, chitinous insects like lice and fleas. Many attempts must be made before one's efforts are successful.

Some form of dissecting microscope is necessary, together with clean instruments, including fine pointed needles and needles which have been ground to a sharp cutting edge on one side.

For purpose of study and demonstration it is well to stain and mount the various organs. The technique used by Patton and Cragg is briefly as follows: Flood with salt solution and remove all parts not wanted and all debris.

Remove salt solution with a pipette or piece of filter paper and arrange the organs in position on the slide.

When the specimen is just beginning to dry allow a small drop of the fixing solution to come in contact with one edge and draw it around the edges with a clean needle. As the material becomes opaque add more of the fixing agent and finally immerse in a Coplin jar full of it for one-half to one hour.

The fixing agent is Bless' fluid composed of,

Formalin	7 parts
Alcohol 70%	90 parts
Glacial Acetic Acid	3 parts

It should not be used more than ten days old.

This fixes the tissue to the slide and also is the fixing agent for the cells of the tissue.

From the fixing agent carry the specimen to 70% alcohol where it may remain until ready to complete the process. Then remove to 80% alcohol for 10 minutes, 95% alcohol for 10 minutes and absolute alcohol for one hour. Reverse the process back to 45% alcohol

allowing a few minutes to each transfer and then overstain in haematoxylin. Staining usually requires several hours. Decolorize in 1/4% acetic acid or hydrochloric acid, watching the progress under the microscope. When sufficiently decolorized carry through the alcohols to absolute, to secure dehydration. Clear in oil of cloves and mount in Canada balsam.

Borax-carmine may also be used as the stain in place of haematoxylin.

To section insects or their tissues one requires a knowledge of histological technique. The technique is the same except that with insects one is dealing with material of very small size. It is better to isolate the organ desired before preparing for section, although whole insects may be sectioned with more or less success. For soft parts only paraffin embedding is satisfactory. It will also answer for mosquitoes. For insects like fleas where much chitin is present the double embedding method (paraffin and celloidin) is better. The celloidin should be allowed to act for some time but there should be a minimum exposure to the paraffin as it tends to make the chitin brittle.

Whole insects may be fixed in formalin solution or in a concentrated solution of bichloride of mercury in alcohol containing 5% of glacial acetic acid. Fresh material should be used. The wings and legs should be removed to permit of better penetration of the fixing fluid. A small opening may be made in the abdomen for the same purpose. Sectioning through chitin is unsatisfactory and a number of sections may have to be made before obtaining good ones. Stiles has had good success in sectioning heavy chitin by first imbedding in paraffin. Before cutting a section paint the top of block with a solution of gum mastic (Mastixharz), using a camel hair brush. Let dry, then cut. Mount section gum side down. The chitin is softest in newly emerged insects. After fixing well, the insect may be put into warm KOH solution (10%) or in Labarraque's solution for a short period.

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PART II

DISEASES OF MAN TRANSMITTED BY INSECTS

CHAPTER XXIV

INTRODUCTION

Arthropods may be divided into those which are parasitic and those which are not. A *parasite* is an organism which lives wholly or in part on the tissues or juices of another usually larger species, the host. A *temporary parasite* visits the host for the purpose of feeding or breeding and remains with the host for a limited period of time only (bed bug, mosquito, bot-fly etc.). *Permanent* parasites remain with the host unless destroyed or removed. Parasites are termed *ectoparasites* when they dwell upon or within the integument of the host, and *endoparasites* when they dwell within the body.

An insect may be *accidentally* parasitic (*pseudoparasitism*) as for example when eggs or larvae of flies are deposited in wounds, in the nose, ears or sinuses, or are swallowed. This is sometimes the case with the blow flies, the screw-worm fly etc. Although out of their natural habitat these immature forms live and grow and by their presence may constitute a disease which may lead to serious results. This condition, where the larvae of flies are involved, is known as *myiasis*. *Myiasis* may also be a manifestation of true temporary parasitism as typified in the bot-flies where part of the life history is alway spent in an animal host.

An arthropod may be of medical interest without being parasitic, the house fly for example.

Non-parasitic arthropods may cause injury and disease in one of four ways:

1. By serving as mechanical agents in the dissemination of infectious material.

2. By biting and stinging, and inoculating a venom.

3. By harboring a parasite which man may acquire through accidental contact.

4. By pseudoparasitism.

The house fly preeminently illustrates the first of these principles. It breeds in filth and feeds upon human filth which it carries in its intestinal tract, on its proboscis and on its feet, back to man usually

through contamination of his food. Thus it may carry diseases of the intestinal type, notably typhoid fever and dysentery, both bacillary and amoebic. In the latter case it is the encysted stage of the *Endamoeba histolytica* which is transported in its intestines.

Certain non-parasitic arthropods although they may be incapable of sucking blood are never-the-less capable of inoculating venom through a bite or sting spiders, scorpions, centipedes, hornets, bees, wasps, etc. While such bites or stings are rarely fatal, serious symptoms may follow and certain individuals who have become sensitized may exhibit anaphylactic phenomena.

The third method by which a non-parasitic arthropod may be dangerous to man is illustrated by the *Cyclops coronatus*, a small fresh water crustacean which harbors the embryos of the Guinea worm (*Dracunculus medinensis*). Man becomes infested by swallowing water containing the infected *Cyclops* which is destroyed by the gastric juice and the embryo worm liberated.

The fourth way (pseudoparasitism) has already been mentioned.

Parasitic arthropods cause injury or disease in two principal ways:

1. By their habits (burrowing or biting) which lead to irritation and subsequent inflammation of the skin, frequently heightened by scratching lice, itch mites etc.; or the habit requiring them to spend part of their life history in an animal host (bot-fly).

2. By the withdrawal of infected blood from a patient and inoculation of another person at a subsequent biting. The transfer of the causative agent of the disease may be effected by. (a) *direct transference* of the microorganism without change or no change other than a simple multiplication within the alimentary tract of the arthropod, as in the case of the *Bacillus pestis* carried by the flea. (b) *Cyclically*, indirect or transference only after part of the life cycle of the infecting organism has been completed in the body of the arthropod host as in the case of the plasmodium of malaria.

Even though they carry no causative agents of disease, all biting blood-sucking arthropods produce a reaction through the bite, because of an irritating principle in the salivary secretion, the degree of reaction depending upon the susceptibility of the individual bitten. The permanent parasites, like the itch mites and pediculi, by reason of their prolonged visitation, numerous bites or special habits, ordinarily cause more or less severe irritation, loss of sleep leading to lowered vitality, or secondary dermatitis.

Some of the most prevalent as well as some of the more serious diseases of man are transmitted by blood sucking arthropods, notably yellow fever, typhus fever, bubonic plague, sleeping sickness, malaria, Rocky Mountain spotted fever, filariasis, relapsing fever, dengue, etc.

In studying a disease the mode of transmission of which is not understood the epidemiologist must always bear in mind the possibility that a blood sucking arthropod may play the principal role in spreading the disease or in fact may be the only means by which it is spread in nature.

If a disease is spread by a blood sucking arthropod the causative agent must be circulating in the peripheral blood of the patient or carrier, either in the plasma or in the cells, at the time of sucking the blood. Conversely, if the causative agent of a disease circulating in the blood stream is locked up in the body so that it does not escape in any discharge from skin or mucous membrane, the disease can only be spread in nature through the withdrawal of the virus by a biting insect or other arthropod, which in due course of time is transferred to another person. Such transference may take place in several ways:—

First. The virus may gain access to the animal host by way of the proboscis during the act of biting. If so, it may be present in the salivary juices injected into the wound as in the transference of malaria; it may be regurgitated from the alimentary canal as in the transference of bubonic plague; it may pass down in the hollow of the labium as in the transference of filariasis; or it may be by simple contamination of the mouth parts of the arthropod, which having recently sucked the blood of an infected person or animal, may be contaminated for a brief period of time and so infect a susceptible person, as is sometimes the case in sleeping sickness.

Second. An insect while engaged in biting may be crushed by the hand and the contents of its body may be inoculated into the skin by scratching, or by rubbing it into the wound made at the time of biting. This occurs in the case of lice infected with the micro-organisms of relapsing fever which penetrate the walls of the alimentary tract of the louse and gain access to the body cavity.

Third. Contaminated feces from the arthropod may be deposited at the site of the puncture made by the bite, the virus then being rubbed in through scratching. This sometimes occurs in the transmission of bubonic plague by the flea and may occur in other diseases,

including trench fever, typhus fever and tick-borne relapsing fever.

It is possible that man may become infected with some microorganisms by ingesting an ectoparasite which is serving as the arthropod host for the microorganism. Among human beings this mode of transmission could only occur accidentally as civilized man does not intentionally eat his parasites, but it is known that white rats become infected with an *Hepatozoon* through ingestion of the rat mite (*Laelaps echidninus*) which transmits the organism from another infected rat. The tape worm of dogs and cats (*Dipylidium caninum*) has been rarely found in man. Infection in man is probably due to the accidental ingestion of dog fleas or lice which harbor the larval stage of the worm.

So far as known it is only in the case of a parasitic *animal organism* that a definite stage in the life cycle of the organism does take place in the body of the arthropod host. When such a stage in the life history of the organism is necessary, a period of time must always elapse between the withdrawal of blood from the patient or carrier and the transfer of the infection to another person. This interval of time is known as the *extrinsic period of incubation*. This period is not always definite for much depends on atmospheric temperature but until it has been completed the arthropod host cannot convey the disease.

The host in which the sexual cycle of the microorganism occurs is known as the *definitive host*. The definitive host is believed not to be harmed by the presence of the organism. The host in which the asexual cycle of the microorganism occurs is known as the *intermediate host*. The intermediate host is harmed by the presence of the parasite. As examples one may mention malaria in which the mosquito is the definitive host for the malarial parasite and man is the intermediate host; or filariasis in which the mosquito is the intermediate host of the filaria and man is the definitive host.

In the case of those organisms known or believed to have a definite stage of their life cycle in an arthropod host the development of the organism is limited to one or at most a few species of the arthropod concerned. For example, malaria can be transmitted only by mosquitoes belonging to the anopheline group and of these only the species of the Genus *Anopheles* serve as the insect carriers. African trypanosomiasis is transmitted by but two species of tsetse fly, *Glossina palpalis* and *Glossina morsitans*, and for that matter,

each of these carries a different species of trypanosome. The transmission of yellow fever is confined to one species of mosquito, the *Aedes aegypti*. As a general proposition the arthropod remains in a condition to disseminate the disease for a considerable period of time, or even throughout its active life. In the case of pathogenic microorganisms belonging to the vegetable kingdom, sojourn in the arthropod is not essential. It is only through force of circumstances that they enter the intestinal tract of the arthropod and they remain there until eliminated through defecation or regurgitation. The body cavity, organs or tissue are not actually invaded. Multiplication of the microorganism may and usually does occur, but ordinarily they are harbored only for a more or less limited period of time, the tendency being for the gastrointestinal tract to clean itself through peristaltic action. This occurs in the case of the flea harboring the plague bacillus. Under such circumstances the minimum period elapsing between the withdrawal of blood from an infected person or animal and the inoculating bite is variable. It may be short, since the mode of transmission is purely mechanical, depending upon the degree of septicaemia in the animal or person bitten as well as upon the rapidity and degree of multiplication in the alimentary tract of the arthropod, the degree of peristaltic action and the bactericidal action of the serum of blood ingested at subsequent feedings.

The causative agent of tularaemia, *Bacterium tularense*, which is regarded as a vegetable parasite, furnishes an exception to the remarks made in the last paragraph. This microorganism seems to be capable of infecting any of the common blood-sucking insects and actually passes through the stomach walls and invades the body cavity. The insect remains infective for long periods.

Some animal parasites in passing through the stage of the life cycle for which an arthropod host is required, are transmitted to the second generation of the arthropod. A classical example of this is found in the case of *Babesia bigemina*, the causative agent of Texas fever, a disease of cattle, which is transmitted by the second generation of ticks. The infected female leaves the infected animal and deposits her eggs containing the microorganisms. The newly hatched larvae seek new animal hosts and transmit the disease to them. A long extrinsic period of incubation is thus required 40 to 60 days, 30 of which are required for development into the larva. Such mode of transmission involving the second generation of the

intermediary host may take place in the case of Relapsing fever of West and East Africa which is transmitted by a tick, and Rocky Mountain Spotted Fever which is also transmitted by ticks. In both of these diseases, however, the adult male and female ticks can transmit the causative agents directly, the spread of neither disease depending upon transmission to the next generation of ticks.

It is possible that some lesions in man attributed to insect bites are, in reality, due to infection by the casuative agents of diseases of lower animals, the germ not coming to full maturity in the human host.

Much remains to be learned about the life histories of pathogenic organisms, animal and vegetable, in their passage through arthropod hosts. The examples cited will serve to indicate what is known of the various ways in which arthropods may transmit disease, and the possibilities which are to be borne in mind.

The above remarks have ignored the possibility that the virus may leave the body of the patient or carrier by other means as well as through the withdrawal of blood. If the causative agent of the disease is present in any of the discharges there is, of course, the possibility that there may be other modes of transference involved. It may happen, however, that notwithstanding the presence of microorganism in one or more of the discharges, transmission in nature can only occur by inoculation through the skin. Trench fever is an example of this principle. The virus is contained in the blood of the patient and also in the sputum and urine but the disease is only contracted through inoculation into the skin, and it is highly improbable that infection could be acquired in this way from urine or sputum except under most unusual circumstances. The natural mode is through the bite of an infected louse.

In studying the relation of a disease to a possible arthropod carrier the epidemiologist should consider the geographical distribution and seasonal prevalence of the disease to ascertain whether these factors correspond to the distribution and prevalence of any arthropod which, in virtue of its life history and habits, could serve as an intermediary host.

The points to be taken into consideration include, the time of year at which the arthropod appears and disappears in relation to the time of appearance and disappearance of the disease; the distribution of the arthropod, whether widespread or limited to certain areas; whether domestic or wild, i.e. breeding in or around

houses or away from houses in woodlands, fields, marshes, streams, mountainous districts, or lowlands, etc.; its habits of breeding and the conditions (including temperature conditions) under which breeding occurs. Does it invade the cities or is it limited to the country; does it enter houses; is it present in large or comparatively small numbers during its period of activity; do its habits bring it into contact with man; does it suck blood and if so will it attack man or is it confined in its feeding to other species; does it prefer one species to another and what is its usual host; does it cling closely to its host or move about actively? What distances are travelled by flight or otherwise? Will it bite at all times or only within certain hours; is there a history of a bite preceding the onset of the disease in human beings, and is there any evidence of an epizootic among lower animals which may serve as hosts for the suspected arthropod?

When an arthropod is suspected of being a host, proof must be sought through experimental laboratory work in attempts to discover whether the suspected arthropod, after having bitten a patient, is capable of infecting susceptible animals or persons through biting; or whether the salivary glands, or the crushed body of the arthropod, or the contents of its gastro-intestinal tract, or its expelled feces, are capable of transmitting the disease to susceptible animals when inoculated. Arthropods which have been allowed to feed on the blood of patients or diseased animals should be permitted to feed on experimental animals for various lengths of time and at different intervals after ingestion of the causative agent is presumed to have occurred. One of the first things to be determined is whether laboratory animals are susceptible by inoculating them with blood, pus or discharges from a diseased person or animal containing either the known microorganism or the unknown virus as the case may be. The possibility that arthropods of the second generation may transmit the disease should be borne in mind. When searching for parasites of animals in an arthropod host it must be kept in mind that insects harbor parasites which are peculiar to themselves and which bear no relation to disease in man. As an example one might mention *Herpetomonas pediculi*, a louse parasite, which forms cysts in the gut, and escapes with the feces deposited upon the human skin. Other lice which feed at the contaminated site are infected through ingestion. Flagellates (*Herpetomonas* and *Crithidia*) are frequently found in insects such as mosquitoes, horse flies, fruit flies, flesh flies, blue bottle flies, the house fly, fleas, lice, etc., and at times it is only

after careful breeding in the laboratory that such parasites can be eliminated, thus avoiding confusion. Even yeast cells in the stomach of mosquitoes have been confused with microorganisms pathogenic to man.

Insects also have their external parasites. One frequently observes fungi and mites parasitic on insects, as well as mites which remain upon the insect to feed upon the juices of the parasitic mites.

CHAPTER XXV

MALARIA

Causative Agent. Malarial parasites which are animal protozoan blood parasites of the Class Sporozoa, Order Haemosporidia and Genus Plasmodium. There are three species as follows:

Plasmodium vivax causing benign tertain malaria

Plasmodium malariae causing quartan malaria

Plasmodium falciparum causing aestivo-autumnal malaria.

Source of Infection. The blood of a person ill with malarial fever or an infected anopheles mosquito. Man is the intermediate host, the mosquito is the definitive host.

Mode of Transmission.— In nature malaria is transmitted through the bite of certain species of infected Anopheline mosquitoes. The disease can also be transmitted by inoculation of infected blood.

Period of Incubation.— About 14 days. Extrinsic period of incubation ten to twelve days.

Period of Communicability.— As long as sexual forms of the malarial parasite are present in the peripheral blood. Carriers in the form of chronic cases are common in malarial sections and are responsible in colder countries for carrying the disease over from season to season. Although a certain number of female anopheles survive the rigors of winter through hibernation, the malarial parasite is carried over in human carriers and not in the mosquito.

Epidemiology.— Malaria is widely distributed over many parts of the world; in the temperate zones as well as in tropics and subtropics. In the United States it is prevalent in the southern states and there are malarial centers in the New England States and on the Pacific Coast of California.

The mosquitoes known or believed to be implicated in the spread of malaria in the United States are:

Anopheles quadrimaculatus, Say (by far the most important vector).

Anopheles crucians, Wiedemann.

Anopheles punctipennis, Say.

Anopheles pseudopunctipennis, Theobald.

Only the female of the species bites; she feeds on blood. The male is a vegetarian. Feeding takes place at night. Anopheles mosquitoes may be said to have two flights, the first beginning at dusk in search of food; the second beginning at dawn in returning to the place of rest or breeding place. It is at dawn that the *A. quadrimaculatus* may be found on house screens. It is then easily killed as it is sluggish when full of blood. Anopheline mosquitoes are much easier to catch than the wary and active yellow fever mosquito.

Anopheles mosquitoes rarely breed in water which is polluted with sewage or where decomposition of organic matter is taking place to any great extent, or in water which contains trade wastes like sulphuric acid, coal gas or oil, soap or grease, etc., nor do they breed in the rapidly flowing parts of streams, nor ordinarily in deep water or water the surface of which is disturbed and ruffled or which is covered by plants forming a dense film on the surface. Fish, predacious water insects such as water boatmen, and tad poles in large numbers may explain the absence of anopheles larvae.

Where Anopheles larvae are found it does not necessarily follow that they are actually producing mosquitoes, for where only young immature specimens are collected it may mean that the conditions are inimical to growth and that none is actually going on to full development. On the other hand, where only large nearly grown larvae are encountered it may mean that they were washed there from elsewhere by heavy rains.

The breeding places of anopheles mosquitoes may be divided into natural and artificial. The first are breeding places of choice, the second are breeding places of necessity or accident. The natural breeding places are shallow shady pools of clean water, large ponds, especially near the edges, streams and ditches, more especially in pockets at the edges, marshy areas containing small pools, post holes, hoof prints, rice fields, and rarely street gutters, etc., in general, clear quiet water,—ponds, swamps, pools, puddles, lakes, lagoons. Aquatic plant life which furnishes shelter and protection to the larvae promotes breeding. Plankton organisms and organic matter furnish food to the larvae.

Among the artificial breeding places in which Anopheles mosquitoes may at times breed are puddles of clear fresh water where some vegetation is present. Such puddles may result from drains from ice plants, leaks from water pipes, fire plugs, pumps, overflows

from watering troughs, tanks, etc. Occasionally breeding takes place in barrels, boats, fountains etc.

Anopheles quadrimaculatus. This mosquito is rather fastidious in its choice of a breeding place and much prefers, clean, clear, quiet water, such as large ponds and grassy puddles. It will not breed in sewage polluted water. It breeds especially in ponds of considerable width and depth but when more favorable breeding places are scarce it occasionally may be found in post holes, and rarely at the edges of slow moving streams where there is practically no surface flow. In ponds it is ordinarily found near the edge in shallow water, sheltered and protected by water plants, but has been reported from the middle of a large pond in 6 feet of water where floatage (broken pieces of blades of wild celery and pollen) furnished protection by preventing any break in the waves, thus permitting only long smooth swells, and also furnishing protection against fish.

A. quadrimaculatus enters occupied dwelling houses in large numbers and therefore comes into intimate contact with people at the time it is ready to feed. It may be guided into the house by lights, even by light reflected up the chimney, and it may enter a house by way of the chimney as well as through unscreened windows and doors. It is also found in out buildings such as privies. It may prefer the blood of man to that of animals. Probably most malaria is contracted at night in the house from the bite of this anopheline. This species may fly as far as 1 1/4 miles from its breeding place. This is perhaps not usual, but from 1/2 to 1 mile is a common flight for *A. quadrimaculatus.* The greater the amount of breeding the greater the number that will be found at a distance from the breeding place, and the greater the tendency towards long flights up to the maximum. *A. quadrimaculatus* is an efficient carrier of *P. vivax*, *P. falciparum* and *P. malariae.*

Anopheles crucians. *A. crucians* is rarely found in inhabited dwelling houses. It is not so widely distributed as either of the other species. It is a porch biter and is commonly found under the house or around the house, in outhouses, privies, stables, etc., and seems to prefer the blood of animals to that of man. Its maximum flight distance is probably the same as that of *A. quadrimaculatus.* It may be found breeding side by side with other *Anopheles* but may adapt itself to brackish water, as in salt marshes, or water containing small amounts of chemicals, conditions under which neither the

quadrimaculatus nor the *punctipennis* will breed. *A. crucians* is a proven transmitter of *P. falciparum* and *P. vivax*.

Anopheles punctipennis.—This mosquito is more widely distributed and more numerous than either of the other species. It is most in evidence in the early evening. Like *crucians* it is rarely found in occupied dwelling houses but is a proch biter and is found under houses and in outhouses, pig pens, and the like. It seems to prefer the blood of animals to that of man. It does not fly far from its breeding places which may be in *streams* and *ditches* as well as in small ponds, marshy areas or other places where *quadrimaculatus* will breed. Slight pollution of the water does not deter it from breeding.

A. punctipennis is a proven carrier of *P. vivax* and *P. falciparum*.

The two latter species of mosquitoes are less important disseminators of malarial infection than *quadrimaculatus* because the Anophelines are shy, and biting outside while persons are moving about is not a common occurrence.

Anopheles pseudopunctipennis.—This mosquitoe is found in the southwestern part of the United States, southern California, and Texas, extending down through Mexico, and Panama into South America. It may enter houses. It breeds in pools, ditches, edges of streams, preferring clear, pure water. *A. pseudopunctipennis* is a proven carrier of *P. falciparum*.

Some other anophelines which may carry malaria and which do carry malaria in other parts of the world are:

Anopheles (Cellia) *albimanus* Wiedemann, (Panama, Brazil, Virgin Islands)

Anopheles (Cellia) *argyritarsus* Robineau-Desvoidy, (Panama, Brazil)

Anopheles (*Cellia*) *tarsimaculatus* Goeldi, (Panama, Porto Rico)

Anopheles minimus Theobald (Philippine Islands)

Anopheles (*Myzomyia*) *ludlowi* Theobald (Philippine Islands, Sumatra)

Anopheles fuliginosus Giles, (Philippine Islands)

Anopheles sinensis Wiedeman (Philippine Islands)

Anopheles (*Myzochynchus*) *barbirostris* Van der Wulp, (Philippine Islands)

Anopheles (*Myzomyia*) *culicifacies* Giles, (India)

Anopheles (*Myzomyia*) *funestus* Giles (Africa)

Anopheles maculipennis Meigen, (Europe)

Anopheles bifurcatus Linnaeus, (Europe)

A. maculipennis is found in the Western United States and is called *A. occidentalis.* *A. albimanus* and *A. argyritarsus* are also found in the United States but have not been implicated in the transmission of malaria in that country.

The life histories of those mosquitoes mentioned above as being carriers of malaria in countries near or forming a part of the United States are briefly as follows:

Anopheles argyritarsus. Found in the Canal Zone, Brazil, etc., breeds in small collections of water such as seepage pools along hillsides, ditches containing only a small quantity of water, foot prints, swampy pastures, and in artificial containers.

Anopheles albimanus. Breeds in fresh or brackish water, even preferring brackish water, but not foul water. It is found in swamps, hoof prints, wheel ruts, and even where there is a very thin film of water, if algae are present. This mosquito enters houses in large numbers.

Anopheles tarsimaculatus. This mosquito breeds in fresh or brackish water, but not in foul water. It has been taken from rivers, swamps, ditches, small holes, hoof marks, and even artificial containers. The larval stage is prolonged to from 15 to 18 days.

Anopheles minimus.—Found in the Philippine Islands, India, etc. Breeds in pools and streams, and enters houses freely.

Anopheles ludlowi. Will breed in very fresh or salt water. It has been taken from small pools, margins of running streams, marshy grounds, and fish ponds. It enters houses freely.

Anopheles fuliginosus.—Ordinarily found breeding in swampy places and pools containing much vegetation. It enters houses freely.

Anopheles barbirostris.—Breeds in shady pools and streams. Feeds in the shade during the day. Rarely enters houses.

Anopheles sinensis.—Breeds in swamps, rice fields and water with much vegetation. Feeds by day. Not often found in houses.

Life History of the Malarial Parasite. (Fig. 92).—There are two different cycles in the life history of the malarial parasites. One takes place solely in the blood of the human host, requiring from 48 to 72 hours for its completion according to the species, and explains the occurrence of the periodic attacks of chills and fever. This is the non sexual cycle (*schizogony*). The other cycle has its beginning in the blood of the human host but is completed only in the body of the mosquito. This cycle is known as the sexual cycle (*sporogony*) and without its completion malaria cannot spread.

In describing these cycles it is convenient to begin at the time of biting when the falciform spore (*sporozoite*) from the salivary glands of the mosquito is inoculated into the blood. The sporozoite then bores its way into a red cell, assumes a spherical shape and enlarges, finally showing division into spore-like bodies. The parasite is then known as a *merocyte*. The merocyte ruptures, the spores (*merozoites*) become free in the blood serum and then enter other red blood cells and the cycle begins anew. This complete nonsexual cycle takes from 48 to 72 hours depending upon the species of malarial parasite. The cycle repeats itself until there are a sufficient num-

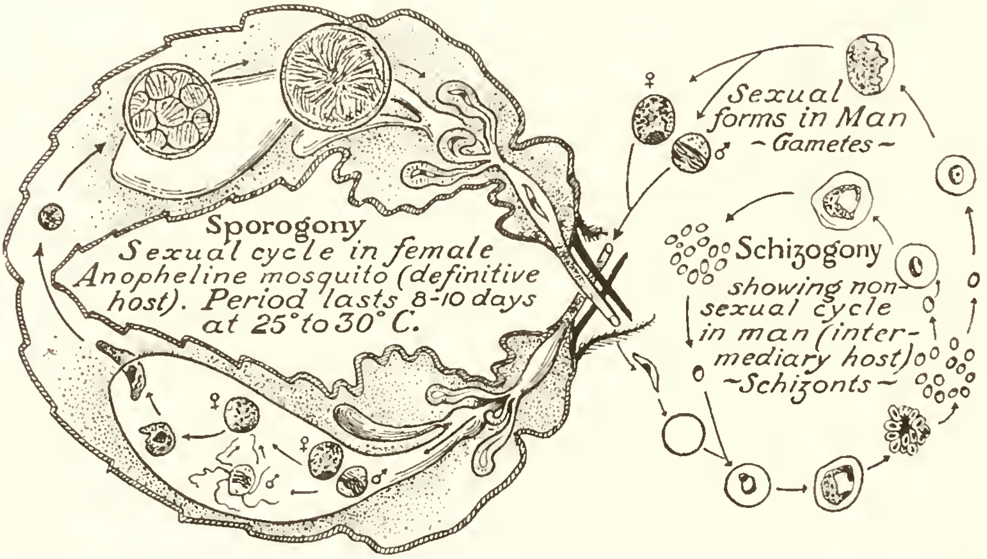

Fig. 92.—Sexual (sporogony in mosquito) and nonsexual (schizogony in man) of the malarial parasite. The sporogony diagram at the left shows in lower portion the fertilization of the female gamete by the microgamete. The vermiculus stage of the zygote is shown boring into the walls of the mosquito's stomach later to become the more mature zygote packed with sporozoites as shown in the upper diagram of the developmental processes in the mosquito's stomach. (From Stitt's "Practical Bacteriology, Blood Work and Animal Parasitology," 7th. Edition.)

ber of merocytes rupturing simultaneously to produce symptoms. This represents a period of about 14 days—the period of incubation.

By and by sexual forms (*gametes*) develop from some of the non sexual forms of the parasite. The female, (*macrogametocyte*) contains more pigment, less chromatin and stains more deeply blue. The male (*microgametocyte*) contains less pigment, more chromatin and stains greyish green rather than blue. These forms undergo no further development within the human host, but when taken into the stomach of a suitable mosquito host, the male gives off spermatozoa like projections (*microgametes*) which break off from the parent

cell and enter a female parasite, which by nuclear changes and formation of polar bodies has become a *macrogamete*. Thus the female is fertilized, producing what is known as a *zygote*. The fertilized parasite then penetrates the outer wall of the mosquito's stomach (midgut) remaining within the stomach wall for about 10 days during which time it enlarges until it becomes a cyst (*oocyst*) filled with hundreds of falciform bodies (*sporozoites*). About the tenth day the oocyst ruptures and the sporozoites are thrown off into the body cavity from which they make their way to the salivary glands, and finally into the blood of man. Thus the sexual cycle ends and a new cycle begins. The essential formula is ten generations of the nonsexual cycle in man alternate with one generation of the sexual cycle in the mosquito. The total time necessary for development in the mosquito is about 10 or 12 days. (The extrinsic period of incubation.) Low atmospheric temperatures delay development, and winter weather stops it altogether.

Economic Considerations.—Malaria is a disease which though not an important cause of death is responsible in districts where it is prevalent for lowering the physical and mental efficiency of large numbers of people to such a degree that economic conditions are seriously affected, resulting in enormous financial loss to the community. In some localities practically entire communities are sufferers from the malady in either its acute of chronic form. An attack does not produce immunity.

Seasonal Prevalence.—In the temperate zone malaria has its highest prevalence and the greatest number of deaths occur rather late in the season, August, September and October, after a considerable period of warm weather, for the malaria mosquito does not ordinarily make its appearance in numbers until July and then can do no harm until 10 or 12 days after it has bitten a patient. When the temperature is below 60°F. mosquitoes do not carry malaria. In the Tropics the malaria mosquito is present all the year round. In the temperate zone it hibernates through the winter neither feeding nor breeding. In the tropics it estivates during the hot dry weather.

Epidemiological Study.—In an epidemiological study of malaria both mosquito and human host must be investigated. A survey to determine the prevalence and location of anopheline mosquitoes will give what is known as the anopheline index to the prevalence of malaria. This should include the collection of specimens and a

search for oocysts within their stomach walls and sporozoites within the salivary glands in order that the percentage of infected mosquitoes among those examined may be determined.

Investigation of the amount of infection in human beings includes a statement from local physicians as to the number of cases treated in the current and previous years, study of the periods of greatest prevalence, information derived from industrial plants relative to loss of time on account of malaria, house to house visits for the examination of all persons to determine the blood index, the history index or the splenic index. The splenic index is sometimes investigated when laboratory examinations are impracticable. It is determined by noting the percentage of persons among those examined who have the enlarged spleen so characteristic of chronic malarial infection. This is a valuable index of malarial infection in the Tropics but it is not so useful in the United States. By the blood index is meant determination of the percentage of persons examined who show malarial parasites in the blood. The thick smear method is better for this purpose as it furnishes a larger quantity of blood, and malarial parasites are therefore more likely to be seen, even though they may be few in numbers in the circulating blood. The blood index is the best index of malarial infection in the United States.

Method of Making Thick Smears and Staining for Malarial Parasites.—1. Before making blood smears have slides and cover glasses scrupulously clean and free of grease. It is well to flame them before using.

2. About one-half drop of blood is smeared out over a surface equaling the size of a cover glass.

3. Allow to dry thoroughly in air. This may take from one to two hours at room temperature or 20 to 30 minutes in the incubator. Protect from dust, flies, ants, etc.

4. Gently move slide about in a 2% solution of formalin to which has been added 1% of glacial acetic acid, until laking is complete.

5. Wash in glass of tap water to remove all acid.

6. Wash gently in distilled water.

7. Stain in weak Giemsa (1 drop to 1 cc.) for 20 to 30 minutes.

8. Wash in water.

9. Allow to dry without heat or use of blotting paper.

Mosquito Survey. To carry on a mosquito survey one needs:

1. One white enameled dipper with hollow handle so that its length may be extended by the insertion of a stick of wood.
2. One wooden extension to handle of above.
3. One medicine dropper with an orifice of about one-eighth of an inch to be used in selecting larvae and pupae from the dipper.
4. One pair of entomological forceps.
5. One entomological bottle or a large test tube at the bottom of which is placed cotton and rubber bands saturated with chloroform covered with a paste board disk and corked. This is used as a catching bottle for adult mosquitoes.
6. Six pill boxes in which to put adult mosquitoes when collected.
7. Six small preserve jars (Mason) in which to place specimens of larvae collected, together with the water in which they were breeding (about half full) covered with mosquito netting, these serve as breeding jars. Small vials in which to place larvae may be taken into the field, and the larvae transferred to the breeding jars in the laboratory.
8. One notebook and pencil.
9. One pair rubber boots.

In making a survey for malarial mosquitoes it is well to collect all kinds of mosquitoes as a matter of scientific interest. All possible breeding places should be looked into even though the prospects of securing Anophelines is remote. In looking for Anophelines the dipper should be used for skimming the surface of the water or it may be lowered into the water allowing the larvae to wash in. Search must be made especially at the edges of ponds and pockets at the sides of streams and where shelter is afforded by weeds, rushes, etc. Before dipping wait quietly for a few moments. Note the number of larvae per dipper and the size; also note the character of the water, whether clear, muddy, stagnant or flowing; presence of fish, tadpoles, water insects, water plants, algae, etc.

All such information should be recorded in the note book together with the location of the mosquito breeding area. Spot maps or charts are valuable. All specimens collected should be labeled with date, time, and place collected, and initials or name of collector.

It is more or less difficult to bring Anopheles larvae to maturity in breeding jars, therefore larger larvae or pupae should be taken preferably.

Recognition of the Disease. Malaria presents so many different clinical manifestations, and the symptoms may be so variable even in

the same type of the disease that it is impraticable to discuss the recognition of malaria from the clinical standpoint in a book of this character. In regions where malaria prevails even the laity are more or less familiar with the disease as it appears in the locality. For the symptomatology of malaria a standard work on tropical medicine should be consulted.

The blood examination is of prime importance, fresh and stained films should be examined.

The following differential tables are taken from Stitt, Diagnosis and Treatment of Tropical Diseases.

UNSTAINED SPECIMEN (FRESH BLOOD)

	P. vivax (benign tertian)	P. malariae (quartan)	P. falciparum (malignant tertian) (aestivo-autumnal)
Character of the infected red cell.	Swollen and light in color after eighteen hours.	About the size and color of a normal red cell.	Tendency to distortion of red cell rather than crenation. Shriveled appearance. (Brassy color.)
Character of young schizont.	Indistinct amoeboid outline. Hyaline. Rarely more than one in red cell. Active amoeboid movement. One-third diam. of red cell.	Distinct frosted glass disc. Very slight amoeboid motion.	Small, distinctly round, crater-like dots not more than one-sixth diameter of red cell. Two to four parasites in one red cell common. Shows amoeboid movement until appearance of pigment.
Character of mature schizont.	Amoeboid outline. No amoeboid movement.	Rather oval in shape. Sluggish movement of peripherally placed coarse black pigment.	Only seen in overwhelming infections. Have scanty fine black pigment clumped together.
Pigment......	Fine yellow-brown, rod-like granules which show active motion in one-half grown schizont. Motion ceases in full grown schizont.	Coarse almost black granules. Shows movement only in young to half-grown schizont.	Pigmented schizonts very rare in peripheral circulation except in overwhelming infections. Tends to clump as eccentric pigment masses almost black in color.

STAINED SPECIMEN

	P. vivax (benign tertian)	P. malariae (quartan)	P. falciparum (malignant tertian) (aestivo-autumnal)
Character of infected red cell.	Larger and lighter pink than normal red cell. Shows "Schuffner's dots."	About normal size and staining.	Shows distortion and some polychromatophilia and stippling. Rarely we have coarse cleft-like reddish dots, Maurer's spots.
Character of young schizont.	Chromatin mass usually single and situated in line with the ring of the irregularly outlined blue parasite.	Rather thick round rings which soon tend to show as equatorial bands.	Very small sharp hair-like rings, with a chromatin mass protruding from the ring. Often appears on periphery of red cell as a curved blue line with prominent chromatin dot. Frequenly two chromatin dots.
Character of half-grown schizont.	Vacuolated or Fig. 8 loop-like body with single chromatin aggregation. Schuffner's dots.	More marked band forms stretching across red blood cell.	Not often found in peripheral circulation. Chromatin still compact.
Character of mature schizont.	Fine pigment rather evenly distributed in irregularly outlined parasite.	Coarse pigment rather peripherally arranged in an oval parasite.	Very rarely seen in peripheral circulation in ordinary infection. Pigment clumps early.
Character of merocyte.	Irregular division into 15 or more spore-like chromatin dot segments. Mulberry.	Rather regular division into eight or 10 merozoites. Daisy.	Sporulation occurs in spleen, brain, etc. Rarely in peripheral circulation. Eight to 10 chromatin staining merozoites. (In culture 32.)
Character of macrogamete.	Round deep blue. Abundant, rather coarse pigment, chromatin at periphery.	Round, similar to P. vivax but smaller.	Crescentic, deep blue, pigment clumped at center, chromatin scanty and in center.
Character of microgametocyte.	Round, light green-blue, pigment less abundant, chromatin abundant and located centrally or in a band.	Round like P. vivax.	More sausage-shaped than crescent. Light blue. Pigment scattered throughout. Chromatin scattered and in greater quantity but difficult to stain.

Prevention and Control of Malaria

The prevention of malaria includes:

1. Measures directed toward the prevention of mosquito breeding and the destruction of adult anopheline mosquitoes.

2. Measures directed toward preventing anopheline mosquitoes from becoming infected by detecting and controlling human carriers and patients.

3. Protection of healthy person:

   (*a*) Through quinine prophylaxis (immunization)

   (*b*) By screening against mosquitoes.

Prevention of mosquito breeding and destruction of adult Anopheline mosquitoes.

The breeding of mosquitoes may be combated by draining, filling, oiling, use of larvacides, fishes and clearing.

Drainage. Drainage may be of the usual horizontal type, or it may be vertical. Hand in hand with drainage must go clearing debris and plants, from the border of streams and ponds; straightening edges and deepening channels so that a free and more rapid flow of water may be had.

Drainage is applicable to ponds, marshes, lakes, puddles and ditches in which water has become stagnant. Temporary puddles should be controlled by oiling; road side ditches should be cleaned and channels leveled out; old wells, cisterns, etc. should be filled, oiled, or treated by chemicals. Marshes, ponds, and lakes especially require drainage. Streams may be straightened, cleaned and made free of vegetation at the edges. All obstructions to the flow of water should be removed.

The kind of ditching necessary to effect drainage depends somewhat upon the extent and kind of area to be drained.

Drainage ditches should have clean cut sloping edges, steep banks, a uniform grade and width, a straight course, and should be free from weeds, stones and sticks, or anything which may impede the flow of water. When bends are necessary, sharp bends should be avoided. The bottom should be narrow so that the flow of water will be rapid rather than slow. As few ditches as possible should be dug. It is best to start with the main ditch, then to build the laterals. Laterals should enter the main ditch at an acute angle, or a curve to lessen the deposit of silt or sand at the junction.

Earth ditches may be expensive to maintain, and to reduce the ultimate cost of maintenance as well as to make drainage more effective, it may be advisable to give them a permanent lining of cement. A rough base of concrete (1:3:5) may be laid on the bottom of the ditch about 1½ inches thick and extending for about 6 inches up the side or 3 inches above the normal water line for small ditches. This should then be covered with ½ inch of cement and sand (1:1). The lining should be U shaped and not V shaped. In large ditches 24 inches or more in width, the lining of the side wall should extend higher and should be thicker. The lining should also extend higher at the bends or key walls should be built. Seepage holes should be provided above the key wall. A lining of concrete 2 inches thick

reinforced with chicken wire is satisfactory, or a rough lining of flat stones sealed roughly with cement mortar may be used.

Sub-soil Drainage is useful to lower ground water, thus permitting surface pools to be absorbed more quickly. For sub-soil drainage ordinary drain tiles are used, from 3 inches to 12 inches in diameter and in 1 to 2 foot lengths. All drains should be spaced from 50 to 150 feet apart and laid up and down the slope. Drains should be from two to four feet deep. The deeper it is the more area drained and the fewer drains needed. They should have a grade of about 12 inches to 400 feet and should be laid so that each piece of pipe touches the other. The joints of course should be loose. The drains should be covered with earth.

When used as intercepting drains for seepage outcrops, the drain must be laid at a right angle to the drainage flow. A grade of not less than 12 inches per 200 feet is required in this case and the tiles should be 1/8 to 1/4 inch apart. The drain should be covered with stones, using small stones at the top, extending above the surface.

Drainage ditches may be utilized to intercept seepage outcrops. They should be dug at a right angle to the seepage flow.

Sub-soil drainage has the advantage over surface drainage of being more easily maintained, because it is self cleaning, needs little attention, and no oiling; besides there is no water exposed in which mosquitoes may breed. The outlet should be guarded by metal rods to prevent entrance of small animals. Such drains should never be used to collect house drainage or drainage in which there is much sediment.

In digging ditches dynamite has been found to be useful. Horse drawn ditching machines are also valuable in constructing ditches less than 3 feet deep in open land, as well as in cleaning out roadside ditches.

Vertical Drainage. Vertical drainage is sometimes used. By this is meant the draining of surface water into a well dug or bored through the upper impervious stratum to a porous or water bearing stratum below.

Filling. Where drainage is not economical resort may be had to filling. In using earth or clay as a fill no depression in which water may accumulate should be left. It may be advisable to fill shallow parts of ponds, thus making it easier to care for the deeper parts.

In a city, such parts of the city's wastes as consist of ashes or rubbish make a satisfactory fill. Ashes and cinders are especially good.

It must be remembered in using old tins as filling material that care be taken to cover them thoroughly with ashes, earth or similar materials, so that no water may accumulate in them to breed mosquitoes. Sawdust and shavings when available may be used as a fill. This should extend several inches above the ground. Wet areas due to seepage outcrops can not be satisfactorily eradicated by making shallow fills.

Clearing.—In order that there will be an unobstructed flow of water in streams and ditches, and that there will be no stagnant pockets in which mosquito larvae may breed, they must be kept free of vegetation and should be kept at a proper grade and proper width. Oil and larvacides should be used when necessary. To kill algae, copper sulphate is efficacious. In dry weather a ditch may become a series of stagnant pools. These may be eradicated by digging small channels in the bottom of the ditch with a spade or hoe. A phosphate drag is useful in clearing ditches of vegetation.

Low ground kept moist by seepage outcrops over which cattle walk, leaving foot prints in which water accumulates, may be fenced off. A barrel should be sunk in the ground at some point outside the fence where it will fill with water and enable cattle to drink.

The use of drainage and fill to combat mosquito breeding furnishes problems with which Sanitary Engineers should be more familiar than Medical Officers. It is work which therefore should be carried on by the former. A successful outcome depends upon the way in which the work is planned and thorough supervision to insure that ditches will have a proper grade and proper width and are properly located, etc. Careful record should be kept of labor, material, and cost.

Impounded Water.—In the season during which mosquitoes are not breeding the level of the water should be kept as high as possible. Before the mosquito breeding season begins the level of the water should be lowered so that all brush and land vegetation which has accumulated along the edges at high water will be killed up to the high water level, and floatage and drift will be left at the high water level when the water falls. During the breeding season water should be kept at as low a mark as possible unless when to do so uncovers growth otherwise submerged.

Oiling.—Oiling is a valuable means of controlling mosquito breeding and oil must always be used for such areas as cannot be treated otherwise. Oiling is not permanent like draining but must

be repeated once a week during the mosquito breeding season. Kerosene will answer the purpose but it evaporates too rapidly. An oil in consistency somewhere between kerosene and crude oil, or fuel oil, is advisable in that it will spread evenly and rapidly and will not evaporate quickly. A suitable mixture is one varying from one part of kerosene to three parts of crude oil, up to 3 parts of kerosene to one part of crude oil, depending upon the thickness of the latter. The resulting mixture should be black in color and should be slightly thicker than kerosene. Fuel oil ranging in specific gravity from 36° to 38° Baumé and in viscosity from 34 to 38 drops per minute is about right. Such oil does not burn readily. Oil that has been drained from the crank cases of automobiles may be used. It is cheap and satisfactory. Only a thin film of oil on the water is necessary, but it should be an unbroken film which should remain for at least 12 hours. It must be remembered that oil may not spread satisfactorily where there is a barrier of vegetation and a larger quantity of oil should be used in such places, or such vegetation may be removed by use of a submarine saw. Oil may be washed away if applied just before a rain storm. Winds may blow an oil film to one shore of a body of water. It is also a waste of oil and of labor to oil where no mosquito larvae are to be found.

Coal oil kills larvae by plugging the breathing tube when they come to the surface to breath, thus asphyxiating them. It also acts as a chemical poison and as a deterrent against egg laying. The amount of oil required to cover a given surface with a satisfactory film varies greatly and depends upon the thickness of the oil, the atmospheric temperature and the presence of water plants. About 1 gal. of crude oil will be required for 150 sq. yds. of clear surface. A greater quantity of oil will be required where vegetation is present.

Oil may be spread by the so called knap sack pump, with the nozzle adjusted to throw a fine spray, or better still with a cylindrical pump which will throw a stream 25 to 30 feet. It may be thrown on the surface of the water in the form of oil soaked sawdust. This is a satisfactory means of spreading oil over the surface in the presence of water plants. The oil soaked sawdust may be encased in a canvas bag or gunny sack and anchored to the bottom of the body of water. The oil is gradually given off and spreads over the surface. Oil soaked waste may also be used.

Drip cans are useful in applying oil especially to streams and ditches in which the current is fairly rapid. The design of a drip

can varies according to the ideas of the operator. Ordinarily five to ten gallon oil cans or drums answer the purpose. Dripping may be brought about by means of a wick or a well fitting stop cock opened slightly so that the desired number of drops per minute may be obtained. The number of drops of oil will depend upon circumstances but in general it may be said that from 10 to 20 per minute are required to treat the surface of a stream or ditch having an average width of water surface of one foot. The object is to allow a sufficient number of drops to form a continuous film. It will be carried down stream and will accumulate on surfaces where no current is present and where mosquitoes are most likely to breed. The stop cock requires attention as it is liable to clog with sediment. For use under water two stop cocks are convenient, one at the top of the can and one at the bottom. A wick requires some attention but it is an easy matter to squeeze the accumulated sediment from it at the time the can is refilled. The wick should be fixed with one end immersed in the oil and the other end in the water so that the oil flows by capillarity. One type of can is placed on supports above the water to be oiled. Another type is sunk to the bottom. Out going oil rises to the top and spreads on the surface. A tiny opening must be left so that as the oil drips out a corresponding amount of water flows in. The surface drip can must also be provided with a means of permitting air to flow into the can as the oil flows out.

A satisfactory drip can may be improvised by punching a hole through the bottom of an ordinary 5 gallon oil can with a 2 or 3 inch round nail. A wad of loose cotton is then wrapped around the nail just below its head and the nail pushed through the hole from the outside. The can is then filled with crude oil. The flow of oil through the drip may be regulated by gently pushing the nail up or down depending upon whether a greater or fewer number of drops is required.

In using heavy oil as a drip the can should be elevated above the stream at least 3 or 4 feet so that the drop of oil will fall on the surface of the water with a splash thus breaking up and spreading more rapidly.

Oiling may be discontinued before cold weather has permanently set in. It must be remembered that when the temperature is below 60° Fahrenheit, *Anopheles* do not carry infection. Either the parasite does not go on to development within the body of the mosquito, or it finally dies out. In the summer time eggs

must be deposited 28 days before the mosquito can infect, that is, it takes 10 days from egg to adult, and the extrinsic period of incubation is 11 days, making 28 days in all. Now as the weather becomes colder this time lengthens more than 50 per cent, making 42 days instead of 28. Theoretically, therefore, it is permissible to stop oiling 42 days before the atmospheric temperature is expected to fall below 60° Fahrenheit. Practically, however, a factor of safety should be allowed, so that oiling should proceed up to 21 days before the advent of cold weather.

Larvacides. The larvacide used in Panama is a good one. It is phenol resin soap, and in the proportion of one part to 1000 parts of water, kills larvae promptly. It mixes quickly with water and tends to remain at the edges of the stream, and that which passes down stream kills as it goes. It is only good for one day and therefore must be repeated once a week. In the same proportion it may also be used in rain barrels and the like, at intervals of one week. Any phenol preparation which has at least 15% of phenol in the crude product is a good larvacide. It must be remembered that phenol preparations are poisonous to fish and of course should not be applied to water which is to be used for drinking or cooking purposes.

To make about three and one half barrels of larvacide take

150 gallons of crude carbolic acid which must contain not less than 15% phenol.

200 pounds of common rosin, finely crushed and sifted.

30 pounds of caustic soda dissolved in six gallons of water.

Heat the carbolic acid in an iron tank by means of a steam coil with steam at 50 pounds pressure, or to 212°F. Dissolve the rosin in the boiling acid and then add the solution of caustic soda. The whole must be thoroughly mixed. The product is ready in a few minutes. This preparation may be used by spraying an emulsion made by mixing one part of the larvacide to five parts of water.

Paris green has been tried as a larvicide, and has been found to be successful in killing larvae of Anopheline mosquitoes. It does not seem to be lethal to larvae of other forms of mosquitoes which are not surface feeders. The paris green is diluted with a large proportion of inert dust. Road dust, fine sand, flour, rotten wood dust and the like may be used. The proportion is about 10 cubic centimeters of paris green in approximately one liter of dust. This makes a very cheap larvicide. Danger of poisoning the water is

almost negligible. Larger proportions than the above may be used without danger, and should be utilized where there is much high grass, reeds, etc. It is used by casting it by hand into the air from the edge of the pond in the direction of the wind, a gentle wind preferably, and a sunny day. The dust settles on the surface of the water. Such treatment is to be given every 10 days. There is little danger of poisoning the operator, but naturally he would stand to windward of the dust cloud, and must avoid inhaling the dust. Not enough paris green is used in the water to injure fishes or domesticated animals which may drink of it.

Another form of larvacide is nitre cake, an acid byproduct obtained from the manufacture of high explosives. To kill all larvae within 24 hours it must be used in the proportion of at least one part of nitre cake to 100 parts of the water to be treated. A 0.5% solution in the water will destroy larvae in 3 days. It is fairly efficient when used in old wells, abandoned cisterns, fire buckets, small stagnant ponds, etc., where there is no danger of poisoning people or domestic animals.

Fish Control. Only a few fish have proved to be really effective in the destruction of mosquito larvae. They are to be found among the top minnows or mummichogs (Poeciliidae) the sun fishes (Centrarchidae) and the minnows (Cyprinidae).

It must be remembered that certain fish, like the carp, which have been suggested as useful in the destruction of mosquito larvae are only of value when young, meaning that their usefulness would be limited to the spring months. Carp have the added value that they feed on the snails which act as vectors for certain important parasites of cattle, sheep and goats.

To be effective, both old and young fish, must have the habit of feeding on mosquito larvae. Also they should be of small size so that they may go into the spaces between stems of water plants in a search for larvae so to speak, as well as to find protection against larger predaceous fish. They should multiply rapidly and should be able to live under a great variety of conditions.

In places where fish control is tried, if only small larvae are found, none large and no pupae, one may be certain that the result is successful.

FAMILY POECILIIDAE. Top Minnows

Gambusia affinis.—In the control of mosquito breeding by the use of fish, the top minnow (*Gambusia affinis*) is the best for ordinary

purposes. This fish is especially suitable because it feeds on the surface, it thrives under a great variety of conditions, it is very prolific, and it will multiply in ponds containing predaceous fish provided that there is shallow water for refuge. It lives in fresh or brackish water. This fish is frequently encountered naturally in water suitable to the breeding of mosquitoes, from Maryland to Florida, in the Mississippi valley from Illinois to Louisiana, in Texas and Mexico. It attains a length of from 1 1/4 to 2 1/2 inches. It does not lay eggs but gives birth to young fish therefore special breeding conditions are not necessary. It is cannibalistic. Chemicals in the water as those from certain trade wastes like sulphuric acid, phenol larvacides, and oil will kill them. The water may also be highly polluted so that mosquitoes such as Culex may breed but the fish will not.

Plant growth in the water, especially when slightly submerged, leaves and stems, or floating vegetable growth, afford protection to larvae against the minnow. The greater amount of protection afforded by vegetable growth the larger the number of minnows required.

This minnow is essentially a still water or a pond minnow. It does not seem to like even moderately running water and therefore it is not worth much as an enemy of *A. punctipennis*.

Fundulus notatus is another top minnow that might be worthy of mention because its range is somewhat farther north than *Gambusia affinis*, it is good in mosquito work but not so good as *Gambusia*.

Lebistes reticulatus: (Guppy, Millions).—This little fish is a native of Surinam, Venezuela, Trinidad and Barbadoes. The males are beautifully colored and attain a length of one inch. The females are somewhat larger and are silvery yellow in color. They are very active, very prolific and viviparous. The female brings forth every 4 to 6 weeks from 10 to 50 fry depending upon the age. Males are ready for breeding when 8 to 10 weeks old, with females of the same age or older. The young grow rapidly and a few hours after birth are strong and active. The guppy is of value only as a means of destroying larvae in warm countries as it would rapidly succumb to the cold weather of the temperate zone. It has been used successfully in the Virgin Islands. It makes a good aquarium fish.

Two other species which are similar in habits and usefulness to *Gambusia affinis* are *Heterandria formosa* (top minnow) and *Mollienisia latipinna*. Their ranges, however, are more restricted.

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The range of the former being from North Carolina to Florida and the latter from South Carolina to Northern Mexico. Both of these species were introduced into the Hawaiian Islands and are reported to have been effective against mosquitoes.

The fishes in the United States destructive to the eggs and larvae of mosquitoes may be grouped as follows: (Economic Circular No. 17, Bureau of Fisheries, Department of Commerce).

North Atlantic division (south to New Jersey and Pennsylvania)

Fresh-water species—

Fundulus diaphanus (Killifish; Spring Minnow; Fresh-water Killy).
Enneacanthus obesus (Little Sunfish; Banded Sunfish).
Enneacanthus gloriosus (Spotted Sunfish; Little Sunfish; Speckled Perch).
Lepomis gibbosus (Pumpkin Seed; Sunfish; Tobacco-box; Common Sunfish).
Notemigonus crysoleucas (Roach; Shiner; Bream).
Carassius auratus (Goldfish).

Brackish or salt-water species—

Fundulus majalis (Minnow; Mayfish; Killifish; striped Killifish).
Fundulus heteroclitus (Mudfish; Mummichog; Minnow; Common Killifish).
Lucania parva (Rainwater Fish).
Cyprinodon variegatus (Sheepshead Minnow; Variegated Minnow; Pursy Minnow).

South Atlantic division.

Fresh-water species—

Gambusia affinis (Top Minnow).
Heterandria formosa (Top Minnow).
Enneacanthus obesus (Little Sunfish; Banded Sunfish).
Enneacanthus gloriosus (Spotted Sunfish; Little Sunfish; Speckled Perch).
Mesogonistius chaetodon (Black-banded Sunfish).
Centrarchus macropterus (Flier; Round Sunfish; Millpond Perch).
Lepomis gibbosus (Pumpkin Seed; Sunfish; Tobacco-box; Common Sunfish).
Notemigonus crysoleucas (Roach; Shiner; Bream).
Carassius auratus (Goldfish).

Brackish or salt-water species—

Fundulus majalis (Minnow; Mayfish; Killifish; Striped Killifish).
Fundulus heteroclitus (Mudfish; Mummichog; Minnow; Common Killifish).
Lucania parva (Rainwater Fish).
Cyprinodon variegatus (Sheepshead Minnow; Variegated Minnow; Pursy Minnow).

North Central division.

Fresh-water species—

Fundulus diaphanus (Killifish; Spring Minnow; Fresh-water Killy).
Fundulus dispar (Top Minnow).

Fundulus notatus (Top Minnow).
Gambusia affinis (Top Minnow).
Lepomis cyanellus (Green Sunfish).
Lepomis gibbosus (Pumpkin Seed; Sunfish; Tobacco-box; Common Sunfish).
Notemigonus crysoleucas (Roach; Shiner; Bream).
Labidesthes sicculus (Brook Silverside).

South Central division.

Fresh-water species—

Fundulus dispar (Top Minnow).
Fundulus notatus (Top Minnow).
Gambusia affinis (Top Minnow).
Centrarchus macropterus (Flier; Round Sunfish; Millpond Perch).
Lepomis cyanellus (Green Sunfish).
Elassoma zonatum (Pigmy Sunfish).
Notemigonus crysoleucas (Roach; Shiner; Bream).
Labidesthes sicculus (Brook Silverside).

Gulf Coast waters.

Fresh-water species—

Fundulus chrysotus
Fundulus nottii (Star-headed Minnow).
Gambusia affinis (Top Minnow).
Mollienisia latipinna.
Centrarchus macropterus (Flier; Round Sunfish; Millpond Perch).
Elassoma zonatum (Pigmy Sunfish).
Elassoma evergladei (Pigmy Sunfish).
Notemigonus crysoleucas (Roach; Shiner; Bream).

Brackish or salt-water species—

Fundulus grandis.
Fundulus similis (Killifish; Mayfish).
Lucania venusta.
Cyprinodon variegatus (Sheepshead Minnow; Variegated Minnow; Pursy Minnow).

Goldfish are especially valuable to destroy mosquito larvae in fountains, aquaria, small artificial ponds and the like.

Tadpoles when present in large numbers are also enemies to mosquito larvae.

For further information on the subject of the fishes which are destructive to eggs and larvae of mosquitoes one should consult the publications of the Bureau of Fisheries, Department of Commerce, Washington, D. C.

Area to Be Controlled. The width of the zone surrounding human habitations in which mosquito control measures should be

instituted depends upon the amount of mosquito breeding. Where heavy breeding is encountered this zone should be not less than one mile in width, and perhaps a mile and a quarter, as this distance represents the maximum flight of *Anopheles quadrimaculatus* and *A. crucians*. Where only light breeding is encountered, from one half to three quarters of a mile is ordinarily sufficient. This distance is likewise sufficient in the case of *A. punctipennis*, the maximum flight of this mosquito being less than that of *A. quadrimaculatus*.

It has not been proved that *A. punctipennis* is really of great importance as a disseminator of malarial infection. To eliminate this mosquito much attention must be paid to streams and ditches in which it breeds. If it could be shown that *punctipennis* was of little importance much work could be avoided thereby saving considerable expense.

Mosquito control measures should always begin well before the mosquito breeding season, and every year before mosquitoes begin to breed, streams and drainage ditches etc., must be put in proper condition to perform their functions well without permitting mosquitoes to breed in them.

Partial control of anopheline breeding will do much towards the control of malaria.

Eradication of Adult Mosquitoes in and around Houses.—It is very important that all *Anopheles* mosquitoes which have gained entrance to the dwelling be killed before they are permitted to escape. Careful search should be made for them on the screens, woodwork, netting, etc., in the early morning when they are full of blood and still sluggish. In this way many infected mosquitoes may be killed.

Land around habitations should be kept free of tall grass and weeds which form resting places and harbor mosquitoes. Such care also permits the ground to dry more readily under the heat of the sun. The placing of land under cultivation is incidentally a means of preventing the breeding of mosquitoes, since such land must be drained except for the growing of rice. The rice paddy is a serious problem because no practical means have been discovered to prevent the breeding of anopheline mosquitoes in rice fields.

Preventive Measures Applied to Malaria Patients and Carriers of Malaria Parasites

All malaria patients should be protected by mosquito bars and treated promptly with quinine.

Treatment of Carriers.—Campaigns against malaria have been carried on solely by treating carriers with quinine in the hope that the carrier state will be overcome and that *Anopheles* mosquitoes even though present will find no infected blood on which to subsist. The treatment of carriers is logical but only when it is attempted, hand in hand with mosquito control. In the absence of anopheline mosquitoes the presence of a human case of malaria is obviously of little moment from the community standpoint. On the other hand, carriers who come into the community unknown to the authorities may in the presence of anopheline mosquitoes, furnish the source from which the community may become reinfected. Very intensive epidemiological work is required for the detection of even a majority of the carriers in a locality in which malaria is prevalent, and ordinarily the disease cannot be controlled by such methods alone, but every carrier properly treated with quinine means one less focus of infection and may mean the prevention of several cases of malaria. Many carriers can be detected in the course of an intensive epidemiological study and these should be treated without charge.

In the routine work of a health department success in discovering carriers must rest largely upon the cooperation of practicing physicians, employers and others in referring suspected carriers for examination and treatment. The health department should provide an approved mailing outfit for submission of blood specimens from patients and carriers. Quinine should be administered to all carriers discovered by laboratory methods. Several methods of administering quinine have been advocated; 5 grains of the sulphate in capsules, three times a day is, perhaps as useful as any or 10 grains every night before retiring, for a period of 8 weeks. If acute symptoms are present at the time the patient is first seen they should be treated by administering 10 grains of quinine sulphate by mouth three times a day for four days followed by the 8 weeks course of treatment.

Protection of Healthy Persons

Quinine Prophylaxis.—When quinine is circulating in the blood many sporozoites inoculated by the bite of a mosquito will be promptly killed before they have time to go on to development. This is the theory of quinine prophylaxis. While quinine in prophylactic doses does not always prevent the disease, visitors to malarious sections should make use of it. For adults 5 to 7 grains may be taken each

morning. For children 2 to 3 grains will suffice; less for infants. Prophylactic doses should be taken throughout the malarial season. The quinine sulphate is preferable, administered in soft pills or in capsules. Prophylactic doses of quinine do no harm, even when taken for prolonged periods. Those who are peculiarly susceptible to quinine can usually become accustomed to it.

It does not always kill all parasites in the blood, but even so will prevent them from multiplying to the point where symptoms are produced. Its use should be kept up for at least a month after cold weather has set in and likewise after leaving a malarious section in order to make certain the destruction of parasites which have survived. Again, to start the use of quinine early, say March or April, may mean the prevention of a recurrent attack.

Screening.—All houses in malarious districts should be screened against mosquitoes. Wire screening should have not less than 16 meshes to the inch when used to prevent the entrance of mosquitoes. A no. 14 mesh if painted will also answer the purpose, and even ordinary mosquito bar material can be made to serve. Galvanized iron makes a good screen, resisting rust for several years. It is cheaper but not as good as copper or bronze wire which lasts for a much longer period without painting. After a couple of years galvanized wire should be painted, care being taken not to fill the meshes with paint to the point that air is excluded thus interferring with ventilation. Common wire screening should be varnished or painted as soon as put into use. Window screens should be kept closed and screen doors should open outward and be provided with a spring so that they will close automatically. Both should be made of well seasoned wood. The lower half of the door and that part which comes in contact with the hand or elbow when the door is pushed open should be reinforced with heavy wire screening of coarse mesh. Fire places with open chimneys should also be screened as well as all other outlets in the house through which mosquitoes may enter. Cracks in outside partitions may be sealed with heavy paper. Open fireplaces may be sealed with muslin held in place by strips of adhesive plaster.

Biologic Barriers.—Advantage is sometimes taken of the fact that the malaria mosquitoes will suck the blood of animals, even preferring animals' blood to that of man. Piggeries may be established well removed from human habitations, but between such habitations and the source of mosquito breeding. In this way, many

of the mosquitoes seeking blood will be intercepted by the piggeries and will not reach human habitations. Such a means of preventing malaria is not by any means perfect, but plays a part in the general scheme of malaria eradication. It is even possible to build pig pens so that they will act as mosquito traps, that is, the mosquitoes may enter but cannot leave, and they can be killed from time to time by fumigation.

From observations made in Denmark, it has been suggested that in a given locality malarial mosquitoes which may have once preferred human blood, may since have developed a taste for animal blood. This might account for the great decrease in prevalence of malaria in certain sections, even though the mosquito is still present. However, it should be pointed out that a gradual but absolute reduction in the numbers of insect carriers will account for the gradual disappearance of the disease even though the insect carrier may still be present. It may not be possible to exterminate a given insect but it is possible to reduce it to a safe minimum.

CHAPTER XXVI

YELLOW FEVER

Causative Agent.—*Leptospira icteroides* described by Noguchi.* This micro-organism will pass through bacteria-proof filters. The temperature range favorable for its growth and multiplication is from 18° to 37°C. (64.4 to 98.6°F.). The most favorable temperature is about 26°C. It is present in the circulating blood of the patient during the first three or four days of the illness.

Source of Infection.—The blood of a patient ill with yellow fever.

Mode of Transmission.—By the bite of an infected *Aedes aegypti* (*Stegomyia fasciata*) mosquito.

Period of Communicability.—During the first three or four days of illness.

Period of Incubation.—Three to six days.

Epidemiology.—The endemic centers of yellow fever are found in tropical America, Mexico, Brazil, Ecuador, Salvador and on the west coast of Africa. Epidemics within these endemic centers are not uncommon. If once introduced the disease may become epidemic in any country where the suitable insect host is present. Yellow fever has made its appearance a number of times in the United States and, before the discovery of the method of transmission, created panics from time to time, especially in communities bordering on the Gulf of Mexico. Its last appearance in the United States was in New Orleans in 1905. The disease is unknown in the Far East, probably because it has never been introduced.

There seems to be little natural immunity to yellow fever. One attack confers immunity and second attacks are very rare. It is less fatal in the younger age groups and in the negro race. Negroes seem to have a certain degree of racial immunity. At least they have the disease in milder form than whites, Indians or Chinese, independently of previous attacks.

*In 1907 Stimpson of the U. S. Public Health Service, working with sections of organs from persons who died from yellow fever, found a microorganism which he termed *Spirochæta interrogans*. This is apparently the same microorganism as Noguchi's *Leptospira icteroides*.

The disease is transmitted in nature only through the bite of an infected mosquito, the *Aedes aegypti*, which is found in many parts of the world; including Cuba, South America, Mexico, United States, Hawaii, the Philippine Islands, Africa, India, etc.

In order to become infected the mosquito must withdraw blood from the patient within the first three or four days of the illness after which a period of extrinsic incubation must elapse. This period never has been found to be less than 12 days and usually over two weeks varying with the temperature. The lower the temperature the longer the extrinsic period of incubation. Once infected the mosquito apparently remains so during her active life, although in the United States the organism dies out in the mosquito during her period of hibernation so that it is not possible for yellow fever to be carried over to another season. An outbreak during the following year is accounted for by a new introduction of the disease. In countries south of the United States where the cold season is much shorter and much warmer the inimical effect of low temperature on the organism within the mosquito might not be felt and so an infected mosquito might be active for a much longer period even into the next warm season. Infection is not transmitted to the progeny.

Habits of the Yellow Fever Mosquito.—The yellow fever mosquito is a small brown mosquito with silver markings on the legs and back. It is quick to avoid capture and to change its direction of flight although it does not fly fast. It flies with its legs spread out and has an annoying hum as it bites, preferring to bite the ankles, under sides of the wrist and back of neck. It bites in daylight, preferring the early morning and late afternoon, but avoids direct sunlight. It is common both in and around houses. The yellow fever mosquito may also bite after dark, as well as during the day. On cloudy days in a darkened room they may spend much of the time resting, preferring dark surfaces like dark clothing on which to rest. The mouth parts of the female only are adapted for piercing the skin. The insect, being very wary, is quite successful in avoiding a swat.

This mosquito is distinctly a domestic mosquito breeding in and around houses in bottles, cans, pots, cisterns, water barrels, buckets, roof gutters, etc., which contain clean, fresh water. In the absence of the usual breeding places, oviposition must, of course take place, and under such circumstances the eggs may be laid in small pools around a house which contain clean, fresh water, perhaps in street

gutters, collections of water in the axils of leaves or in knot holes in logs and trees. If hard pressed it has been found even breeding in slop jars and chambers containing dirty water. When found breeding in unusual places it is likely that complete development rarely takes place. While this mosquito may not mind some dirt in the water it is not a cess pool breeder.

The eggs of *Aedes aegypti* are laid a little above the margin of the water on the sides of the receptacle, at intervals commencing from 1 to 7 days after feeding. They are laid singly in small groups not in rafts like the *Culex*. They develop in from 2 to 8 days into larvae which in about a week become pupae. These in turn develop in about two days into the fully formed insects. The eggs are fusiform in shape and roughened in pattern, giving them a pearl necklace-like appearance at the margins.

The distribution of the yellow fever mosquito is limited to the area between 38° North latitude and 38° South Latitude. Above or below these boundary lines the cold weather is inimical to the life of the insect. In the tropics it is present all the year round. In the sub-tropics where the colder weather brings frost, some of the females hibernate through the winter as on the Gulf Coast of the United States. Eggs have been found to retain their vitality for five months or even longer out of water, and probably this is the usual means of surviving through the winter. The yellow fever mosquito does not fly far from her place of birth, rarely more than 100 yards or as far as the houses of adjoining neighbors. Their flight is, therefore, extremely limited but they may be carried great distances by ships and occasionally by train.

Recognition of the Disease.—Early diagnosis of yellow fever is highly desirable. However, diagnosis is difficult in the early stages and in mild cases, or in some instances one cannot make a positive diagnosis. In a group of cases diagnosis should be easier. The disease comes on suddenly. About one-half of the attacks commence at night. The pains and malaise are much greater than one would expect from the temperature which is rarely over 103.5°F. In light cases the temperature is highest on the first day; in moderately severe cases, on the first or second day when it commences to fall. The temperature is a continuous one and reaches normal on the 4th, 5th or 6th day. The headache is severe and invariably present. There is troubled sleep or insomnia and restlessness. The facies are characteristic early in the disease. There is intense active capillary con-

gestion of the skin and mucous membranes, producing injected and watery conjunctivae. The upper lip is swollen and the whole face puffed and red. The gums, tongue and fauces are red.

Too much dependence must not be placed on early yellowing of the conjunctiva as an aid in the diagnosis as it will ordinarily be found especially in the tropics, that many persons have some icteric tinge to the conjunctiva due to other causes. Following the sthenic stage on about the third day comes the stage of calm which is frequently very short indeed. It may not be accompanied by any cessation of the temperature but the distress, restlessness and pain disappear and the patient is very tired, too tired to speak or even move a finger. The mind is clear. Stasis or passive congestion now take the place of the active congestion of the first stage. The face is a dusky yellow, the conjunctivæ are still red but dry and show the tortuous veins. The conjunctivæ are now distinctly yellow and the gums are red, spongy and bleed spontaneously or on very slight pressure. This bleeding may be elicited by pressing the finger lightly over the upper lip, not directly on the gums. If the nail be drawn across the skin on the chest, a yellowish line will be left which finally turns red and lasts for some time. The stomach is frequently painful, always tender. This may be elicited by pressure over the epigastrium.

In the more severe cases nausea will now return after being absent since the onset of the disease and gastric and intestinal hemorrhages may occur. Jaundice, which was first noticed in the sclerotics may now be general although frequently it does not make its appearance until convalescence. While the mind is usually clear and alert, violent delirium may be present.

Albuminuria is generally found on the evening of the third day and if not present by the fourth day, it is rarely found later. Albuminuria comes on even with very little fever, in an amount out of all proportion to the rise of temperature and increasing in amount with a falling temperature. Albumen making its appearance earlier than the third day is a point indicating an unfavorable prognosis. It is well to look for albumen at the very beginning of the disease as it may be present from some other cause.

Yellow fever is not a disease of high temperatures, not usually rising over 103.5°F., though fever of 104° or 105°F. may occur. The pulse is rather characteristic. At the beginning of the disease, it is higher than it should be for the amount of temperature, perhaps ten or twenty beats; it then commences to drop, the distance between the

pulse and temperature curves, increasing as the disease progresses. There is nothing characteristic about the blood picture. There may be leucopenia, leucocytosis or the blood count may be normal.

Yellow fever must be differentiated from malarial fever, dengue, influenza and measles. The principal points to be remembered in the symptoms and signs of yellow fever are the early appearance of the albumen, facies, jaundice, tendency to hemorrhages, tenderness in the epigastrium, lack of correlation between pulse and temperature, and a clear mind. The leucopenia of dengue, Koplik's spots of measles and the plasmodium of malaria should be kept in mind, although it must be remembered that finding the plasmodium does not exclude yellow fever, as both infections may co-exist, and that leucopenia may be present in yellow fever. Where one is not able to make an early diagnosis of yellow fever, it is better to wait until the temperature becomes more typical, applying preventive measures just the same. It is a serious thing to pronounce dengue fever yellow fever and still more serious to miss a case of yellow fever by calling it dengue.

Upon post-mortem examination cloudy swelling and fatty degeneration of liver cells will be noted. The liver is yellowish in color and oily on section. Icterus is marked. The endothelial cells of capillary blood vessels undergo degeneration. The kidneys are swollen and congested and show evidence of fatty degeneration. Hemorrhages may be noted in the skin as well as mucous and serous membranes. The stomach and intestines contain disintegrated blood. The spleen does not show any change.

Methods of Prevention and Control.—There are two important facts to be kept in mind; first, that without the yellow fever mosquito, yellow fever cannot spread even though a case is introduced into a community; second, that the yellow fever mosquito cannot become infected unless it has bitten a yellow fever patient some time during the first three or four days of the illness. The essential things to be done in the control of yellow fever are to protect the patient against the bite of a mosquito from the very beginning of the disease; to protect all persons from being bitten by mosquitoes, by screening houses and sleeping under mosquito nets; to eradicate yellow fever mosquitoes by oiling, screening or eliminating their breeding places.

Early Recognition.—Early recognition is essential. To be on the safe side during an epidemic or threatened epidemic, every case

of fever should be placed under a mosquito net, even though the disease may not prove to be yellow fever. Experts familiar with the signs and symptoms of yellow fever should be available to assist practicing physicians to make the diagnosis, clinically and at necropsy. It is advisable to inspect all dead bodies during a yellow fever outbreak.

Reporting.—All cases of yellow fever should be reported immediately as well as all suspicious cases.

Placarding.—The house should be placarded.

Isolation.—Isolation under a mosquito net in a screened room should be required. It is not necessary though better to remove a patient to an isolation hospital where the proper precautions can be taken.

Quarantine.—Quarantine may not be necessary, but contacts should have their temperatures taken twice a day for six days, and should be required to report to the health officer the minute they feel ill. Contacts should be vaccinated.

Fumigation.—Disinfection is not required. Fumigation to kill mosquitoes should be practised in a screened room to which the patient should be transferred, after which the rest of the house, including the room previously occupied by the patient should be fumigated to kill mosquitoes.

Screening.—As a community measure screening on a large scale is impracticable, as a protection to himself and family each householder should screen his house against mosquitoes, using a wire screening with a mesh not less than 18 to the inch.

General Measures.—The work of eradicating yellow fever mosquitoes must be carried on energetically by an organized corps consisting of laborers working under the supervision of inspectors. The city should be divided into districts, and a sufficient number of laborers and inspectors assigned to work therein so that the territories can be covered once a week. Their duties are to hunt out all places in which yellow fever mosquitoes are breeding and do away with them by spilling, filling, oiling, screening. Rubbish, like tin cans and old bottles that may hold water, and therefore serve as breeding places for mosquitoes, should be collected and disposed of adequately. Bottles may be broken and tin cans smashed, so that they cannot retain water. Cisterns and rain barrels give a great deal of trouble. Those which cannot be done away with as is the case in many instances, should be oiled once a week, or made mos-

quito proof by tight covers or some form of screening which will not permit the ingress or egress of mosquitoes. Care must be taken to screen the openings for ventilation.

The International Health Board has been very successful in the use of fish for the extermination of larvae of the *Aëdes aegypti* in Nicaragua, Peru and Ecuador. The fish are placed in wells, cisterns, rain barrels, water bottles,—in fact in all but the smallest water containers. In Peru a fish known locally as **Chalaco** has been found to be the most useful. In Nicaragua the *Poecilia sphenops* has been successfully used, which is probably the same fish as one used successfully in Peru known locally as the *Chalquoque*. Other fishes used in Peru are known locally as **Life, Majarra** (*Aequidens rivulatus*) **Cachuelo, Tripon,** and **Bagre** (a small cat fish).

When it is possible to empty containers, it should be done once a week and the containers then exposed to the sun for three hours before refilling. Straining out the larvae has been tried in an effort to save the water. The successful use of fish in water containers makes the entire problem a much easier one to solve. It must not be forgotten that even very small collections of water in and around the house may breed *Aedes*, as for instance, in the base of flower pots, in the water pan of a grind stone, baptismal fonts, tins containing water in which the legs of tables have been placed, roof gutters, and a host of other places that may easily escape notice. Roof gutters should be repaired so that they drain completely.

A campaign of education should be carried on so that people would understand what is being done for their good, and what they should do to help out the situation.

Carter points out that in a small city where there is more or less yellow fever, where there is no immigration, and where the only increase of population is due to the births within its boundaries, yellow fever tends to die out, because eventually an immune population develops, and there is no susceptible material left, or at least there is so little of it, that the probability of a chance infected mosquito coming in contact with the right person is very remote. Of course, given a sufficient length of time during which there is a gradual accumulation of susceptible material, a fresh introduction of the disease might be the beginning of a limited outbreak depending upon the amount of available material present and the prevalence of the mosquito.

It cannot be expected nor is it necessary that all mosquitoes of the species *aegypti* be exterminated. All that is necessary is to reduce their numbers to a minimum. This minimum may be considered as having been reached when it is shown that mosquito breeding is taking place on not more than 1% of the premises comprising the infected community. This percentage may be increased depending upon the number of immune persons among the population. The greater the number of immunes the higher the percentage of safety based on the number of breeding places. On the other hand in a community with a large susceptible population, where yellow fever is introduced, the anti-mosquito work must be all the more intensive.

"Breeding" is not to be considered as synonymous, with "production." In fact in mosquito work it is quite a different matter. Where only small larvae are encountered no large larvae and no pupae, it may be assumed with certainty that the anti-mosquito work is successful and that while breeding may be taking place, no larvae will go on to the "production" of adults.

Immunization.—Noguchi has developed a serum which promises very good results when used on or before the third day of the disease. He also reports favorable results following the use of a protective vaccine made from killed culture of *Leptospira icteroides*.

A Guide for Formulating a Mosquito Ordinance

The following outline for a Mosquito Ordinance has been suggested by the U. S. Public Health Service (Public Health Reports, April 2, 1920). Like all model ordinances it may require some modification in order to adapt it to local conditions.

Model Ordinance

SECTION 1. It shall be unlawful for any person to have, keep, maintain, cause, or permit within the corporate limits of... ....any collection of standing or flowing water in which mosquitoes breed or are likely to breed, unless such collection of water is treated so as effectually to prevent such breeding.

SECTION 2. Collections of water in which mosquitoes breed or are likely to breed are those contained in ditches, ponds, pools, excavations, holes, depressions, open cesspools, privy vaults, fountains, cisterns, tanks, shallow wells, barrels, troughs (except horse troughs in frequent use), urns, cans, boxes, bottles, tubs, buckets, defective house roof gutters, tanks of flush closets, or other similar water containers.

SECTION 3. The natural presence of mosquito larvae in standing or running water shall be evidence that mosquitoes are breeding there.

SECTION 4. Collections of water in which mosquitoes breed or are likely to breed shall be treated by such one or more of the following methods as shall be approved by the health officer:

(*a*) Screening with wire netting of at least 16 meshes to the inch each way, or any other material which will effectually prevent the ingress or egress of mosquitoes.

(*b*) Complete emptying every seven days of unscreened containers, together with their thorough drying or cleaning.

(*c*) Using a larvicide approved and applied under the direction of the health officer.

(*d*) Covering completely the surface of the water with kerosene, petroleum, or paraffin oil once every seven days.

(*e*) Cleaning and keeping sufficiently free of vegetable growth and other obstructions, and stocking with mosquito destroying fish.

(*f*) Filling or draining to the satisfaction of the health officer.

(*g*) Proper disposal, by removal or destruction, of tin cans, tin boxes, broken or empty bottles, and similar articles likely to hold water.

SECTION 5. In case the person responsible for the condition of premises on which mosquitoes breed or are likely to breed fails or refuses to take necessary measures to prevent their breeding within three days after notice in writing has been given him by the health officer, or within such longer time after such notice as may be specified in the notice, the said person responsible shall be deemed guilty of a violation of this ordinance; and for each day after the expiration of three days from the day on which such notice is given him, or for each day after the expiration of the time specified in the notice, as the case may be, that the person responsible fails or refuses to take such measures, the said person responsible shall be deemed guilty of a separate violation of this ordinance, and in case of such failure or refusal of the person responsible the health officer is authorized to take necessary measures to prevent the breeding of mosquitoes, and all necessary costs incurred by the health officer for that purpose shall be a charge against the person responsible.

SECTION 6. For the purpose of this ordinance the person responsible for the condition of any premises is the person using or occupying the same; or, in case no person is using or occupying the premises, the person who by law is entitled to the immediate possession of the same; or, in case the premises are used or occupied by two or more tenants of a common landlord, or form grounds appurtenant to a house occupied by two or more tenants of a common landlord, then the landlord; each tenant, however, is responsible for that part of the premises which he occupies to the exclusion of the other tenants: *Provided*, That, in case the premises are occupied by a tenant under a yearly or monthly tenancy, or under a lease for not more than a year, or under any lease whereby the lessor is expressly or impliedly obligated to keep the premises in repair, and the collection of standing or flowing water in which mosquitoes breed or are likely to breed is owing to the disrepair of the building or buildings, or to any natural quality of the premises, or to any condition that existed at the time when the tenant entered into possession, or to anything done on the premises by the landlord during the existence of the tenancy or lease, then, and in such case, the landlord is the person responsible: *Provided further*, That any person who has caused to

exist on any premises of which he is not the owner, landlord, occupant, or tenant any collection of water in which mosquitoes breed or are likely to breed is responsible, as well as the owner, landlord, tenant, or occupant, as the case may be.

Section 7. For the purpose of enforcing the provisions of this ordinance, the health officer, or his lawful subordinate, may at all reasonable times enter in and upon any premises within his jurisdiction.

Section 8. Any person found guilty of a violation of this ordinance, as described in section 5 hereof, shall be punished by a fine of not less than one dollar ($1) and not more than twenty-five dollars ($25).

Section 9. This ordinance shall be in full force and effect on and after the ....day from the day on which it is approved.

CHAPTER XXVII

DENGUE FEVER

Causative Agent.—Unknown. A filterable virus which is present in the blood of patients from the second to the fifth day.

Source of Infection.—The virus circulating in the blood is transmitted from the patient to a well person through the bite of a mosquito, *Aedes aegypti* (*Stegomyia fasciata*). The disease may also be transmitted by the direct inoculation of blood from a patient.

Period of Communicability.—In order to withdraw the virus the mosquito must bite the patient from the second to the fifth day of the disease.

Period of Incubation.—Three to ten days.

Epidemiology.—Dengue fever is a disease of tropical and subtropical countries and is common in India, China, and the Philippine Islands. A number of epidemics have occurred in the Southern United States. It appears in epidemic form spreading rapidly, and attacking large numbers of people at or about the same time, like epidemic influenza. It attacks both sexes. There is no racial immunity. Death rarely occurs. One attack gives but uncertain immunity. The extrinsic period of incubation is indefinite. There may be two similar diseases included under the term Dengue fever.

The distribution of dengue fever corresponds rather closely to the distribution of *Aedes aegypti* which in the United States is not found further North than about 38°.

Habits of the Aedes aegypti (Stegomyia fasciata).—See Yellow Fever.

Recognition of the Disease.—The disease sets in abruptly with intense supra and post orbital headache, and chilly sensations. There are pains in the back and very severe pains in the muscles and around the joints. The temperature rises rapidly to 102° or 105° F. The face is blotchy, the eyes are injected, the mucous membrane is flushed. The pulse rate may be slow but usually varies directly with the temperature. There is great depression, both mental and physical, malaise, loss of appetite, etc. The temperature remains high for three or four days when it drops and is followed by a period of

remission during which the patient feels comparatively well. This period of remission is sometimes extremely short and may pass unnoticed, or it is usually somewhat indefinite lasting from 12 hours to three days. After the remission the fever again rises abruptly and the patient is even more severely ill than he was during the first stage. The latter stage, however, does not last so long. The rash, which is more or less typical of the disease, may appear with the intermission or with the second rise of temperature. It first appears on the dorsal surface of the hands and feet and the forearms and legs and afterwards may be more widely spread. It is somewhat variable, sometimes absent or at least very evanescent. It has been described as a rash more like measles, but it is as frequently a punctate decidedly bright rosy blush, disappearing on pressure more like scarlet fever. With the drop in temperature there may be epistaxis, profuse sweat or diarrhoea. Leucopenia is marked and is found early in the disease, about the second day. There is also a reduction of polymorphonuclear leucocytes. Albuminuria is absent. Dengue fever must be differentiated from yellow fever and influenza, as well as from measles, scarlet fever and even variola.

Methods of Control.—The patient should be kept covered by a mosquito net at least five days from the beginning of the diseases Destruction of the mosquito is called for. (See yellow fever.)

CHAPTER XXVIII

FILARIASIS

Causative Agent.—Filariasis is caused by a thread-like round worm, Class Nematoda and Family Filariidae, the embryos of which can usually be found circulating in the blood sometime during the 24 hours. There are at least five more or less important species affecting man as follows:

Filaria bancrofti, the adult forms of which are located in the lymphatics and lymphatic glands.

Loa loa *Onchocerca volvulus* *Acanthocheilonema perstans* *Dracunculus medinensis*	the adult forms of which are located in the connective tissues.

Of these *Filaria bancrofti* is the most widespread and is the most important.

FILARIA BANCROFTI

Source of Infection.—The adult worms are located in the lymphatic system. The embryos known as microfilariae are found circulating in the blood at night, and not at all or in very small numbers during the day.

Mode of Transmission.—Transmission from person to person is brought about through the bite of an infected mosquito, commonly *Culex quinquefasciatus*, although other mosquitoes have been implicated.

Period of Communicability.—As long as microfilariae are circulating in the blood.

Period of Incubation.—Indefinite.

Epidemiology.—Filariasis is a disease of tropical and subtropical countries. In the United States cases have been traced to Charleston, South Carolina, where the infection is present. It affects any age and either sex.

Man is the definitive host. It is in man that the sexual cycle occurs, and damage is done by the presence of the filariae only by

accident so to speak. The fully formed embryos (microfilariae) do no harm even though they may be present in large numbers. They are small enough to pass through the capillaries. An accumulation of adult worms, or perhaps embryos given off prematurely when they may be coiled or looped, may offer an obstruction in the lymphatic vessels or give rise to irritation. The mosquito is the intermediate host. It suffers from the presence of the larval filariae. Its life is shortened.

The habits of *Culex quinquefasciatus* indicate strongly that it is the common transmitter of *Filaria bancrofti*. It is domestic in its habits breeding in and around houses in receptacles containing filthy water, in cesspools, open sewers, catch basins, accumulations of water in city dumps etc. In the house it is especially voracious at night and therefore bites when the microfilariae are present in the peripheral blood in largest numbers. Where the disease is present, *Culex quinquefasciatus* is also found. However the mosquito is common in many places where the disease has never been known to occur.

Life History of Filaria Bancrofti.— It is convenient to start with the embryos circulating in the peripheral blood. They do not multiply in the blood. They are taken into the stomach of the mosquito during the act of biting. Neither do they multiply in the stomach of the mosquito. If only one is taken in only one can be given out. Within the stomach of the mosquito, the embryo sheds its sheath, makes its way through the walls of the stomach and into the thoracic muscles where it undergoes a metamorphosis becoming a larva. After a variable time, about two weeks, the larva migrates through the connective tissue spaces to another part of the mosquitoes body, that is, it may pass towards the abdomen, into the legs, into the head, into the antenna etc., or into the labium. In the latter event, it is in a position to pass out and infect an individual. When the infected mosquito bites, the stilette bundle penetrates the skin, while the labium, which does not enter the skin, bends under like a bow, its distal end touching the skin with the labellae spread out steadying the piercing organs. The filaria coming down through this labium pierces Dutton's membrane, and is deposited on the skin of the human host. It then wriggles its way through the skin into the lymphatic system where it matures and becomes a sexually developed adult. Here nothing further occurs unless a representative of both sexes happens to find its way into the same gland. In this event one female may produce as many as 1000 embryos or more at one time.

The embryos then escape from the lymphatic system and circulate in the blood as microfilariae. The cycle is then complete.

The adult male filaria is about 1 1/2 inches long, the female about 3 1/2 inches. The microfilariae are about 30 times longer than and about as wide as the diameter of a red blood cell.

The periodicity displayed by the microfilariae of *Filaria bancrofti* seems to bear some relation to the hosts periods of sleeping, for it has been observed that in persons like night watchmen who sleep during the day, instead of during the night, microfilariae may be observed in greatest number during the day.

Complications and Sequellae of the Disease.— Persons may have filariasis without knowing it or the disease may manifest itsself by attacks of fever and lymphangitis, filarial orchitis and hydrocele, dilatation of the lymph vessels, varicose veins, chyluria, lymphuria, elephantiasis etc.

Other Filariae

Loa Loa.—Mention should be made of *Loa loa* which is found on the west coast of Africa and disseminated by the mangrove fly, *Chrysops dimidiata*. The adult lives in the connective tissues and may wander about so that its course may be marked by an oedematous track. It is more frequently noted about the region of the eye. The microfilariae circulate in the blood as in the case of *Filaria bancrofti* but are diurnal in their periodicity. For this reason the parasite has been called *Filaria diurna*.

Dracunculus medinensis.—Related to the Filariae is *Dracunculus medinensis* or Guinea worm as it is sometimes called. Males and females live in the connective tissue about the mesentery. After fertilization has taken place the males probably die and the females migrate downward towards the legs and feet. Arriving under the skin the female bores her way through its deeper layers, a little bulla on the surface marking her presence. Contact with water causes the bulla to burst and the embryos to be liberated. When discharged into the water of a stream or pond the embryos are taken in by a small crustacean, *Cyclops*, which when imbibed by man with the drinking water dies in his stomach. The embryos are released, bore through the stomach wall and find their way to the connective tissue of the mesentery, where they develop into adults thus completing the cycle.

CHAPTER XXIX

PAPPATACI FEVER

(Three Day Fever)

Causative Agent.—Unknown. A filterable virus, perhaps a *Leptospira*.

Source of Infection.—The blood of the patient during the first 24 hours of the illness.

Mode of Transmission.—The blood is withdrawn and infection transmitted to another person through the bite of a moth midge, *Phlebotomus papatasii* Scopoli of the Family Psychodidae. Other species of the genus can also carry infection.

Period of Incubation.—The period of incubation is from 3 to 7 days. The extrinsic period of incubation is from 7 to 10 days.

Epidemiology.—This fever is probably rather wide spread, in coastal areas in tropical and sub-tropical regions of both hemispheres. It has been studied in the Balkan States, also reported from Haiti, India, Malta etc. It is a disease of the late spring and summer. One attack produces an immunity, but relapses may occur. It is rarely fatal. It is not unlikely that the fly may transmit infection to her offspring.

Phlebotomus papatasii.—This dipteron is a hairy little insect about $^{1}/_{12}$ inch in length. Its small size enables it to pass through a very fine mesh. It is a vicious biter. Only the females bite, and that after sundown and principally in the house. It avoids wind and bright daylight. During the day the midges rest in cool, dark places, in houses, hollows of trees, in latrines, etc. A full meal of blood is taken after fertilization, and then the eggs are laid in damp places, in cracks in bricks, rocks, stones, in caves, etc. The egg takes from 4 to 14 days to hatch, according to the temperature. The larvae are attached to the surface on which they live. The larval stage lasts from 8 to 28 days.

Recognition of the Disease.—The disease resembles very closely dengue fever except that the fever only lasts about three days and there is no secondary rise. The pulse is slow and there is no eruption.

Leucopenia is present. Other fevers have been described as seven day fever, six day fever, and it is very likely that these are dengue fevers where the fever is continuous.

Methods of Control.—The patient must be screened the first two days of the disease. The mesh must be very small (45 meshes to inch) as it is very difficult to keep the moth midge out.

Abolish the breeding places, by leveling, filling and tamping; removal of moist debris; permitting access of sunlight; painting crevices; whitewashing, painting, tarring etc.; cutting weeds so that holes may be filled and sheltered hiding places abolished.

CHAPTER XXX

TRYPANOSOMIASIS

Causative Agents.—There are a number of different species of Trypanosomes affecting animals but so far only three have been definitely identified with disease in man namely, *Trypanosoma gambiense* and *Trypanosoma rhodesiense*, causing African Sleeping Sickness, and *Schizotrypanum cruzi* which is the cause of South American Trypanosomiasis.

Trypanosomes affecting lower animals are as follows:

T. evansi causing "surra" in horses and mules in India, Philippine Islands etc.

T. brucei causing "nagana" in horses, mules, dogs and cattle in Central and South Africa.

T. equinum causing "mal de caderas" in dogs and horses in South America.

T. equiperdum causing "Dourine" a disease of horses contracted through coitus and seen in India, North Africa, and at times in Europe and North America.

T. lewisi of rats which apparently produces no ill effects on its host.

These Trypanosomes are probably carried by non-biting flies which may deposit Trypanosomes on sores, and by biting flies such as Glossinae, Stomoxys, and Tabanidae. *T. lewisi* is transmitted by the rat flea and perhaps the louse. Whether all of the above Trypanosomes of lower animals are distinct species is doubtful. A few cases of infection of man from some of these Trypanosomes have been reported.

AFRICAN SLEEPING SICKNESS

Causative Agent.—*Trypanosoma gambiense* and *Trypanosoma rhodesiense*.

Method of Transmission.—The parasites are carried from the sick to the well by certain biting Muscoidean flies, the Tsetse flies, comprising the genus *Glossina*. Two species of Glossinae are

involved, *Glossina palpalis* carrying *T. gambiense*, and *Glossina morsitans* carrying *T. rhodesiense*. Other members of the genus do not carry the disease. The fly is the definitive host and man is the intermediate host. The disease is transmitted by the fly mechanically or cyclically.

Source of Infection.—The causative agent is found in the blood, in the enlarged lymphatic glands and, in later stages of the disease, in the cerebro-spinal fluid. It is taken from the blood by the fly at the time of biting. It must be kept in mind that certain of the large wild animals of the locality and cattle may also act as reservoirs of infection.

Period of Communicability.—As long as there are trypanosomes in the peripheral blood and a sufficient number of insect hosts in the locality.

Period of Incubation.—Ten to twenty-one days.

Epidemiology.—Sleeping sickness is found only in certain parts of Africa never in districts where the tsetse fly is not found. On the other hand there are districts in Africa where the fly is found but the disease is absent. In such districts the introduction of a case of the disease would probably result in its spread. A tsetse fly has been found in Arabia but the disease has never been reported from that country. Cases have been introduced into the West Indies and rarely a case is imported into the United States but secondary cases never occur because the insect host is not present.

On the West Coast of Africa where the disease has been present for many years, though endemic it does not become epidemic. This suggests that long exposure to the infection among a people produces a certain degree of immunity.

All ages and both sexes are susceptible.

The tsetse fly does not fly far from its breeding places which are in the jungles bordering streams. It has been estimated that the flight distance is not more than 80 yards but they may be transported much further by boats and other vehicles or on animals. They subsist on the blood of warm blooded animals (perhaps the crocodile as well) and bite in the day time principally around mid-day. The larva is carried in the abdomen of the female until it is nearly ready to pupate when it is extruded and in a short time finds its way into the ground about the roots of trees to enter the pupal stage, which lasts about one month. A second larva may be produced in about two weeks.

The disease may be transmitted either direct (mechanically) when at the time of biting the fly is harboring trypanosomes on or in its proboscis, as would be the case when it had just bitten an infected individual. It is very persistent in its efforts to secure a full meal of blood, biting person after person if disturbed, until it is replete. The disease may also be transmitted cyclically i.e. after a change has occurred in the trypanosomes and they have invaded the salivary glands. Briefly the changes that take place consist of a multiplication by division in the stomach of the fly and the development into long highly motile bodies which in 12 to 20 days find their way into the salivary glands where in 2 to 5 days they undergo fission forming what appears to be minute trypanosomes. High atmospheric temperature hastens, low temperatures retard development. The extrinsic period of incubation under favorable conditions is from about 20 to 24 days.

Recognition of the Disease. Three stages of the disease may be recognized.

In the first stage the patient is apparently well or only slightly sick with light intermittent fever, some muscular weakness and increase in pulse and respiration rate after slight exertion. There are no mental symptoms. Enlargement of the superficial cervical lymph glands can be detected and trypanosomes can be demonstrated in the blood drawn from these glands and usually from the peripheral circulation.

In the second stage the symptoms mentioned above become more pronounced and mental disturbances begin to manifest themselves. Trypanosomes are present in larger numbers.

In the third stage mental symptoms are pronounced. There are mental dullness, apathy, hesitancy of speech, lack of interest in surroundings, tremors of hands and tongue and finally coma and death. In this stage trypanosomes are also found in the cerebro-spinal fluid.

Methods of Control. The following have been attempted or advised.

Location of camps away from streams or even the removal of whole villages to locations unsuitable to the propogation of the tsetse fly.

Personal protection against the bite of the fly especially during the day.

Cleaning out underbrush and low-lying branches at the location of fords, wharves, villages, washing places and sources of drinking water etc.

Isolation of infected individuals, protecting them from the bite of the fly and treating them with atoxyl-tartar emetic.

Prevention of the migration of infected persons to non-infected regions where the tsetse fly is present. The enlarged cervical glands and the detection of the parasites in blood aspirated from these glands are practical points in the diagnosis when attempting to restrict immigration.

SOUTH AMERICAN TRYPANOSOMIASIS

South American Trypanosomiasis is caused by the *Schizotrypanum cruzi* which is transmitted by a bug, *Conorhinus megistus*, a winged form of the Order Hemiptera. This insect lives in inhabited houses and is a vicious biter, biting especially on the face. Children are most frequently bitten and are therefore most liable to contract the disease.

The disease may be acute or chronic. The acute disease develops with fever, first continuous, with not more than the usual morning fall and evening rise and is accompanied by oedema of the face. It finally becomes remittent with periodic intervals. During the fever trypanosomes can be found in the peripheral blood. There is enlargement of the thyroid and cervical lymphatic glands, spleen and liver. Transient oedemas may appear. Death may ensue or the disease may assume the chronic form which in type may be myxoedematous, pseudomyxoedematous, cardiac or nervous. South American Trypanosomiasis is associated with a high case fatality rate.

CHAPTER XXXI

TULARAEMIA

(Deer Fly Fever)

Causative Agent. *Bacterium tularense*, a small non-motile, gram negative micro-organism, occurring in the rod and coccus forms, stains readily with aniline gentian violet, difficult to stain in tissues.

Source of Infection.—Material from the gland of the infected person or the blood of the infected animal. The urine and nasal secretions may also produce the disease. In Utah, the jack-rabbit is probably the important reservoir of the infection in nature. The infection is also present among the ground squirrels of California (*Citellus beechyi*) and the lesions produced are quite similar to plague. It is probable that the disease in rabbits has a wide distribution in the United States.

Method of Transmission.—The disease is transmitted to man by the bite of a horse fly, (*Chrysops discalis*, one of the so-called deer flies) which has previously bitten an infected animal. Those butchering or dissecting infected animals may also develop the disease. In fact, the causative agent seems to be capable of passing through the unabraded skin.

Period of Communicability.—As long as the causative micro-organism exists in the peripheral blood of the animal reservoir. It is rare to recover the causative agent from the peripheral blood of a human case. It may remain in the arthropod host for long periods.

Period of Incubation.—Within forty-eight hours.

Epidemiology.—The micro-organism was first described in 1911 by McCoy and Chapin who recovered it from ground squirrels (*Citellus beecheyi*) in California, which were affected with a plague-like disease. Wherry in 1913, 1914, and 1916 described three cases of infection in man in Cincinnati, Ohio. All had ulcerative conjunctivitis, enlarged glands of the neck, and general symptoms. One was a butcher, one was the wife of a farmer, who had handled wild rabbit meat, and the *Bacterium tularense* was recovered from rabbits found dead on a farm four miles distant from the farmer's residence.

The third case was in a domestic who two days before had prepared wild rabbits for the table. The disease has also been reported in Washington D. C. among market men who handle wild rabbits.

The fly-borne disease, Tularaemia,* seems to be confined to a section of the United States corresponding to the distribution of the fly, especially Utah and Idaho. Like plague, it is primarily a disease of rodents, man being infected by accident. Jack rabbits are the reservoirs of infection in Utah although the disease may also affect the ground squirrels (*Citellus mollis*) of the locality and perhaps other rodents. It is not unlikely that the disease is spread from rabbit to rabbit by means of the rabbit tick (*Haemaphysalis leporis-palustris*) and the rabbit louse (*Haemodipsus ventricosus*) as laboratory experiments show that infection may readily occur in this way. It is also present in nature in the Rocky Mountain spotted fever tick of the Bitter Root Valley.

The longest time which elapsed between the time of biting an infected animal by the horse fly and subsequent development of the disease in healthy animals after being bitten by the same flies was 4 days, although by inoculating the body of the infected flies they were found to be infective up to 14 days. The longer they were kept the less tendency they showed to be infective. The process of transference of infection is probably mechanical.

The disease may affect all ages and both sexes, but particularly attacks those working in the fields. The seasonal prevalence corresponds to the seasonal prevalence of the fly, June, July and until late in August. The fly bites on the exposed surfaces of the body.

In the laboratory, successful transmission experiments have been carried out with the horse fly (*Chrysops discalis*) the stable fly (*Stomoxys calcitrans*) the rabbit louse (*Haemodipsus ventricosus*) the mouse louse (*Polyplax serratus*) the ground squirrel flea (*Ceratophyllus acutus*) the bed bug (*Cimex lectularius*) and the tick (*Dermacentor andersoni*).

Recognition of the Disease.—The site of the bite can usually be observed as an ulcer. The adjacent glands are practically always swollen and tender and usually suppurate.

The disease comes on suddenly and is very disabling, often causing two or three months of sickness. There are fever, pains, and

*This name was given to the disease by Surgeon Edward Francis, U. S. Public Health Service. He was the first to recognize the condition as being a manifestation of *Bacterium tularense* infection in man, and to study thoroughly its etiology and epidemiology.

great debility. The mortality is low. Diagnosis can be made readily by inoculating infective material taken from the enlarged glands of the patient into guinea pigs or rabbits subcutaneously in the region of the abdomen and subsequent recovery of the micro-organism from animals which usually die within a week showing hemorrhagic oedema at the site of inoculation, enlarged lymph glands of the groin undergoing granular caseation and great numbers of small necrotic foci in the spleen and liver.

The best mediums for original isolation of the micro-organism from animals are: serum-glucose-cystine-agar or coagulated egg yolk, glucose-blood-agar, or serum-glucose-agar. To both of the latter should be added a good sized piece of the spleen of the infected animal, thus inoculating and enriching at the same time.

The blood of the patient will give a positive agglutination reaction.

CHAPTER XXXII

PLAGUE

Forms of Plague. Three clinical forms of plague have been described, bubonic, septicaemic, and pneumonic plague. The first is the common form and reveals itself by the formation of a characteristic bubo in one of the glandular regions. It is primarily a disease of rodents, from which it is transmitted to man by a biting insect, a flea. Septicaemic plague is that form which develops as a septicaemia from the very beginning, a primary bubo being absent, or the patient dying early before the characteristic bubo manifests itself. This form of the disease is also due to the bite of an infected flea. It is not unlikely that septicaemic plague is frequently a form of bubonic plague in which the bubo has been overlooked, but may be disclosed at autopsy. Practically every case of bubonic plague is septicaemic some time during its course. However, a form of plague, the so-called ambulant plague, has been noted, in which the patient is only mildly ill and able to go about. Here the causative agent is probably limited to the glands. Pneumonic plague is that condition in which there is primarily a pneumonia caused by the plague bacillus. It is spread direct from man to man as in the case of other diseases of the respiratory type. A secondary plague pneumonia is at times found as a complication of one of the other forms of plague, and it is likely that under suitable conditions this may be the start of an epidemic of primary pneumonic plague. These conditions seem to bear a close relation to low atmospheric temperature and tightly closed overcrowded rooms in which a high degree of relative humidity occurs.

Causative Agent.—Plague is caused by the *Bacillus pestis*, a nonmotile, gram-negative bacillus characteristically staining at the poles and sometimes taking on a coccoid form in the tissues. Even the coccoid form retains the tendency to polar staining. The microorganism is found in the plague pustule when that is present and in the bubo in great numbers, in the blood, spleen and liver and in foci of infection in the lungs.

BUBONIC PLAGUE

Period of Communicability.– The disease is communicable as long as septicaemia exists and the suitable insect host is present.

Method of Transmission. Bubonic plague is primarily a disease of rodents, commonly rats, and it is transmitted from rodent to rodent and from rodent to man by a flea which has previously bitten a septicaemic plague animal.

Period of Incubation. The period of incubation is from two to five days, usually two or three days.

Epidemiology. Plague is a disease of great antiquity. Many of the plagues written of in history were bubonic plague, notably the one which spread throughout the Roman Empire in the sixth century, and the great plagues of Europe in the fourteenth, fifteenth and seventeenth centuries. In 1665 it was estimated that in London alone 68,596 people died of plague. In more recent years the disease has visited many parts of the world, including the United States, Porto Rico, Philippine Islands, Hawaiian Islands, Australia, South Africa, Peru, Ecuador etc. Epidemics of bubonic plague have occurred annually in India and China during the past thirty years, and the disease is common in Egypt, Senegal and Uganda in Africa.

Plague is introduced into a country through the migratory habits of rats resulting in their being transported from place to place by ships. This means that practically every port of entry is open to the danger of the introduction of plague infection. Rats may also be carried in freight trains. From ships they land by way of cargoes, gangways and hawsers.

Epidemics of bubonic plague are accompanied by epizootics among rodents. Of all rodents, the rat is the one to be given greatest consideration from the standpoint of prevention. The fact that an epizootic in rats precedes and is coincident with epidemic plague in man has been observed for many years, but it was not until a number of years after Yersin discovered the plague bacillus in 1894, that the true relation of the disease in rats to the disease in man was understood. To account for the transmission of the disease from one animal to another the insect theory was advanced, and in recent years the British Indian Plague Commission, as well as other investigators, have proved conclusively that the flea is responsible. Their experiments were numerous and extensive. They permitted direct contact of a plague rat with a healthy rat in the absence of fleas and found that the healthy rat remained well, whereas when fleas were

introduced the healthy rat contracted the disease. A single flea may transmit the disease. The Commission found that only in rare instances did a healthy rat contract plague by eating the carcass of a plague rat. They were able to produce plague in guinea-pigs by permitting them to live in houses from which plague cases had been taken, but they were able to prevent infection by placing the animals in cages hung above the jumping distance of fleas or by surrounding the cage with sticky fly paper. The experiments were varied in many ways. Plague bacilli were readily demonstrated in the stomach and intestines of the flea after biting a septicaemic plague rat, as well as in the fecal discharges. Inoculation of the material into rats or guinea-pigs produced plague.

Ordinarily the introduction of a case of human bubonic plague into a community would be, in itself, of little moment, although small, self-limited epidemics of the disease may have occurred as a result of direct transference of plague bacilli from man to man by the human flea (*Pulex irritans*) or the bedbug (*Cimex hemipterus* or *C. lectularius*). However, this is more or less a theory and at any rate must be of rare occurrence. On the other hand, the introduction of a rat infected with plague might be a serious matter. Its presence would be unknown and the gravity of the situation would not be realized until the infection among rodents had become widespread and human cases began to appear. The finding of human bubonic plague indicates the necessity for immediate investigation with reference to rat infection.

Other rodents which are known to be concerned with the spread of plague are, the ground squirrel of California (*Citellus beecheyi*) and the Siberian marmot (*Arctomys bobac*). The flea concerned is the one having the plague animal as its normal host. For instance in the case of rats it is either *Xenopsylla cheopis*, the common rat flea of India and which is also found in the United States, or, *Ceratophyllus fasciatus*, the common rat flea of Europe, also more or less prevalent in the United States. In the case of the California ground squirrel the flea concerned is either *Hoplopsyllus anomalus* or *Ceratophyllus acutus*. The flea of the Siberian marmot is *Ceratophyllus silvantieri*.

The incidence of bubonic plague shows a marked seasonal variation depending upon climatic conditions. A moist atmosphere at a temperature of approximately 70 degrees F. is most favorable to the production of an epidemic. Cold winters and hot dry summers are unfavorable. This is because atmospheric temperature and

humidity, especially the latter, have an important bearing on flea breeding and flea longevity. Epidemic plague attains its greatest proportions when rat fleas are most prevalent i.e. when breeding has been most active and when fleas can survive longest after their normal host (the rat) has succumbed to the disease.

When atmospheric conditions are favorable fleas can live for considerable periods of time even unfed but Bacot and Martin have shown that the survival of *X. cheopis* apart from its host is in inverse proportion to the saturation deficiency of the air or, in other words, it is proportional to the rate at which the flea looses moisture. It has also been shown that egg laying and the development from egg to adult are most active when the weather is wet and the temperature moderate and least active under dry and hot conditions.

It is reported from India that in Belgaum plague can only assume epidemic proportions in the latter half of the year, July to November, and at this period rat fleas are most prevalent averaging in July, August and September 18 fleas per rat, while in non-epidemic seasons the average is only 4 or 5 per rat.

Bacot states that to induce ova of *X. cheopis* to hatch, a temperature of over 60 degrees F. seems to be necessary while *C. fasciatus* can hatch at an average temperature of 41 degrees F. The larvae of *X. cheopis* cannot survive below 40 degrees F. while *C. fasciatus* finds this temperature quite suited to its needs. In its reactions to temperature eggs and larvae of *P. irritans* resemble more closely *X. cheopis*. Experiments with the pupal stage gave results similar to the larvae. Bacot further states that at 45 to 50 degrees F. with nearly saturated air fleas can live for many days unfed:—*X. cheopis*, 38 days; *C. fasciatus*, 95 days; *P. irritans*, 125 days; *Ct. canis*, 58 days. Kept in the ice-box and fed on the normal host *X. cheopis* lived 100 days; *C. fasciatus*, 106 days; *P. irritans*, 513 days and *Ct. canis*, 234 days. Under natural conditions they would probably live longer.

Bacot also states that *X. cheopis* has the habit of spending more time on the rat than in the rat's nest while the reverse is true of *C. fasciatus*.

The seasonal prevalence of bubonic plague is naturally not the same in all countries for, as has been said before, it is dependent upon climatic conditions. For instance, in certain parts of India plague is most prevalent in the first half of the year, the epidemic reaching its height in the early Spring; in other parts of India the epidemic

reaches its peak in the Fall months, in Egypt the greatest number of cases occurs during the Spring months; in those parts of the United States and England which have been visited by bubonic plague, cases in man begin in the late spring or early summer and attain their greatest numbers in the late Summer or Fall months. There are parts of the world where climatic conditions are favorable to the spread of plague during any month of the year, and there are parts of the world, as for instance the North Atlantic seacoast of the United States, which, so far as known, have never been visited by plague and where the disease might not be able to survive for any length of time even though introduced. Robertson suggests that atmospheric humidity and temperature are such that the flea population is reduced to a safe minimum during a larger part of the year.

There are parts of India which have never experienced an epidemic of plague not-with-standing they are near to and have free communication with regions where plague is prevalent. Rats are present, rat fleas are present and climatic conditions are favorable during some part of the year. Major Cragg has shown that the rat flea which predominates in these areas is *Xenopsylla astia* or *X. brasiliensis* and not *X. cheopis* although the latter is present in smaller numbers. Differences in habits of *X. astia* may account for the absence of plague. *X. astia* is the predominating rat flea in Colombo which is remarkably free of plague. It is possible that *X. cheopis* is the true plague flea and that while other rat fleas may carry plague under experimental conditions they do not usually do so in nature.

It is not always possible to trace with certainty the source of infection in every human case. A case may develop in a house which so far as known may be free from rats and which may have no known relation to a plague focus. Epidemiological study must include not only an investigation of conditions on the premises where the case develops but also conditions at the place of work, or the place where the patient eats, plays or visits. The guinea pig control may enable one to trace the source of infection, even though a search on the premises for infected rats has not been successful.

Too much stress must not be laid upon the possibility of carrying plague fleas in clothing as a factor to account for the development of human plague, for it is probably an unusual way. When infected fleas are carried they are usually transported on the body of the rat during its wanderings from place to place. It is not necessary to

assume that rats always travel on foot. Many times they are carried in merchandise or in freight cars and escape with their fleas upon reaching the point of destination. This explains why plague may appear in a town far removed from the original focus of infection, the intervening towns having escaped. In rural districts rats often occupy nests of other animals such as the rabbit, squirrel, or field rat. There is then a transfer of fleas between different rodents and thus the possibility of transferring infection to the rodents common to rural districts. This has been the case with regard to the ground squirrel of California and accounted for the finding of infected wild rabbits in England and field rodents in South Africa.

Plague attacks all ages and both sexes. It is more liable to attack those whose habits of living and occupation bring them in more or less direct contact with rats, such as crews of ships, stevedores, dock laborers, stablemen, warehouse men, etc. or those who permit their houses to become rat infested. In ports the highest incidence is likely to occur in the vicinity of the water front and along or near water ways. It is not necessarily confined to such areas however, because through their migratory habits, rats may carry it to many parts of the city and into the country districts.

Where the black rat is present, it is the greatest menace. It is a climber and inhabits the upper parts of a dwelling thus coming into closer contact with the occupants. The gray rat is a burrower and prefers the lower floor, the cellar, or outside of the house.

Plague organisms taken into the stomach of the flea undergo multiplication but do not penetrate the stomach walls and therefore do not gain access to the body cavity, salivary glands or reproductive organs. They are therefore not transmitted to the second generation nor are plague bacilli passed out in the salivary juices. The flea gradually rids itself of plague bacilli through the peristalic movement of the stomach and intestines. Chick and Martin have shown that at times the gizzard becomes so packed with plague bacilli that the minute chitinous teeth are clogged and prevented from closing thus leaving an opening from the stomach to the oesophagus, plague bacilli then develop in the oesophagus, regurgitation readily takes place and the microorganisms pass into the wound made at the time of biting. The fact that the gizzard is choked with bacilli interferes with the passage of blood into the stomach and requires a flea to bite oftener in its efforts to get nourishment. The process of infection is purely mechanical and not biological as in the case of

infection with malarial parasites through the agency of a mosquito. Fleas may remain infective for 15 days or even more, perhaps for 45 days without feeding on blood. An older theory to explain the method of inoculation took into consideration the fact that the contents of the rectum and therefore the expelled feces contained many virulent plague bacilli and that like other parasitic insects the act of biting was often accompanied by the act of defecation. It was therefore assumed that infective fecal matter deposited near the bite was afterwards rubbed in by scratching. No doubt infection does occur in this way as well as by the other method.

For some time it was doubted that rat fleas would actually bite man but it has since been proven by a number of observers that both *X. cheopis* and *C. fasciatus* will readily feed on man's blood. *Leptopsylla musculi* will occasionally bite. Both species of fleas of the California ground squirrel as well as the flea of the Siberian marmot have been shown to bite man. *Ctenophthalmus agyrtes*, a flea of the field mouse which was taken during a flea survey from rats trapped in the country districts of England, was found not to bite man. It has been known for years that not only the human flea but the cat, dog and rabbit flea bite man.

Recognition of the Disease. The disease develops suddenly with a rapid rise of temperature, reaching 103 or 104 degrees F. in two or three days, after which it is more or less irregular. There is headache; the eyes are injected and the facies are characteristic of extreme illness. Prostration is profound and comes on early. Delirium also appears early. The characteristic lesion of the disease, the bubo, usually is sufficiently pronounced by the second day to be readily detected. The most common site for the bubo is the femoral or inguino-femoral region, then the axillary region, cervical, iliac and popliteal. Over the enlarged glands oedema appears and pressure elicits great tenderness. The individual lymph nodes cannot be palpated. This swelling forms the primary bubo. Secondary buboes may appear in other parts of the body. In these, the glands are not matted together as in the primary bubo. Four forms of skin eruption may be described a petechial eruption, ecchymoses, a subsuticular mottling, and the so-called plague pustule. The petechial eruption is not often seen. The petechiae are usually scattered, and with regard to location and numbers are not characteristic as in the case of typhus fever. Ecchymotic areas may be present and just before death there is a subcuticular mottling, somewhat resembling

cadaveric lividity, but not confined to the dependent portions of the body. It is due to the intense toxemia which produces changes in the blood and in the walls of the smaller capillaries. An interesting lesion is the so-called plague pustule, a bullous-like formation containing thin, turbid material teeming with plague bacilli. It is believed to indicate the original point of inoculation, the flea bite. Extending from this to the nearest lymphatic glands, faint red lines indicating lymphangitis, may be observed. A secondary pneumonia due to the deposit of plague bacilli in the pulmonary tissues may occur. In about a week, if the patient survives, the bubo breaks down leaving an ulcer which heals slowly. The post mortem picture is very striking. All glandular regions should be laid open to disclose buboes. These have been described as primary and secondary. The latter are divided into buboes of the first and second order. The primary bubo is typical. It consists of a hemorrhagic, necrotic mass of lymphatic glands matted together and surrounded by a serosanguineous exudate. A serogelatinous exudate, which may be found extending from the glands along the lines of the intermuscular fascia is very characteristic. A secondary bubo of the first order very closely resembles a primary bubo. It is located in the set of glands adjoining the primary bubo and results from extension of the inflammatory process by contiguity. A secondary bubo of the second order is one located in a glandular region far removed from the primary bubo. In these the glands are distinct, firm, and hyperemic on section. Many glands of the body will show this reaction. The spleen is enlarged and firm, although the pulp is congested and friable. The other organs show the effects of a virulent toxemia; petechial hemorrhages on the serous surfaces, cloudy swelling of the kidneys and heart muscle and a congested liver. Necrotic foci may be found in internal organs. The lungs are congested and may show areas of plague pneumonia.

In suspected cases it must be borne in mind that the laboratory furnishes a ready means of making an early diagnosis. It is an easy matter to recover plague bacilli from material aspirated from the bubo, and the causative organism is usually found in the blood. Such material should be obtained from every case as soon as plague is suspected. The material should be stained by a weak solution of an aniline dye, such as carbol-fuchsin. Ordinarily, great numbers of a bipolar staining organism are found, appearing typically as bacilli but not infrequently as coccoid forms which are equally

characteristic. Some of the material should be spread on agar and also planted in bouillon. Guinea-pigs should invariably be inoculated by the cutaneous method.

Prognosis.—The case fatality rate varies greatly, from 30 to 75%.

Treatment.—In the treatment of plague large doses of Yersins serum should be used. The serum should be fresh, certainly not more than 6 months old and should have been kept in the cold. Its value should have been demonstrated before issue by experiments to determine its protective power when used on guinea pigs and white rats. A dose of serum as a curative agent in plague should be 150 to 200 cc. each day until decided improvement is observed. It may be administered subcutaneously or intravernously. The use of serum does some good. Perhaps reducing the case fatality rate 10 to 15%. Unfortunately it is a serum higher in bactericidal than in antitoxic properties and therefore destroys the bacilli thus liberating the endotoxin which, because of the weak antitoxin properties of the serum, is not completely neutralized.

Persons exposed to infection are some times given a prophylactic dose of Yersins serum. The passive immunity produced is fleeting lasting probably not more than one week. 10 cc. is a prophylactic dose given subcutaneously. The local reaction is sometimes annoying and a general reaction sometimes follows.

The use of Haffkine prophylactic, consisting of dead plague bacilli, is not recommended as it is doubtful whether success obtained following its use is commensurate with the time, trouble, and expense entailed in its administration. Theoretically it should be of great value for it should produce an active immunity of much greater duration than the passive immunity following the use of serum. 0.5 to 4 cc. are injected subcutaneously according to age and size of the individual, followed in 10 days by a second inoculation of a still larger amount.

Plague in Rats.—As has been said before bubonic plague is primarily a disease of rodents. During the height of the epizootic, pathological findings are usually very characteristic. There are five signs to be observed. First, the bubo. This consists of a mass of enlarged firm lymphatic glands, necrotic on section and surrounded by a sero-sanguineous fluid; second, there is an injection of the subcutaneous tissue often intense and of a crimson hue, third, the spleen is enlarged, firm, dry and mahogany red; fourth, the

liver may be studded with pin head areas giving it a speckled appearance; or it may have smaller gray points of necrosis; fifth, pleural effusion may be observed.

The location of the bubo depends upon the site of inoculation (the flea bite). In India when single buboes only were present 75% were found to be in the cervical region. In San Francisco, 75% were found to be in the inguino-femoral region. While in New Orleans only 43% were observed in the groin, 28% being located in the neck and 23% in the axilla.

When plague is in abeyance, as between out-breaks, post-mortem signs of plague in rats are not so characteristic. One may observe only the speckled appearance of the liver or there may be larger necrotic areas (plague abscesses) in the liver, spleen, or glands, indicative of sub-acute and chronic plague in rats. According to Williams there may be no macroscopic lesions whatever and yet animal inoculation may disclose the presence of plague bacilli. If while still trapping intensively a period passes without having found a plague rat by the macroscopic method, the possibility that some plague rats in which all macroscopic signs of plague are absent may have been overlooked, must be kept in mind. In fact, it is perhaps better, as plague rats become increasingly difficult to find by the macroscopic method and plague seems to be disappearing from the community, to inoculate material from the combined spleens of a number of rats from the same location; otherwise a focus of infection might be missed, and rat proofing operations could therefore not be put into effect.

Plague produced artificially in rats differs somewhat from natural plague in the pathological findings in-as-much as the glands while sometimes enlarged and injected rarely show the typical, firm, caseous bubo surrounded by an infiltrated area so commonly seen in naturally infected rats. It is, however, common to find that the enlarged glands have a number of yellowish points just under the capsule. The liver has granular lesions similar to the liver of natural plague infection, however if the rat lives for six days or longer, larger necrotic foci replace the usual appearance. The spleen is found to be mottled more frequently than in natural plague and larger granules are more common. Subcutaneous injection is rarely so well marked. Pleural effusion is common. Local reaction is usually quite marked, at the site of inoculation.

Plague in Ground Squirrels.— The bubo is nearly always present involving one or more glands. Most commonly in the inguinal region, next the cervical and then the axillary. The area around the bubo may be hemorrhagic and may show gelatinous infiltration but in many instances there are no changes in the surrounding tissue. On section the bubo is seen to be either blood stained, rather dry and necrotic, or it may contain a purulent mass. (Probably a later stage of the first.)

The spleen is usually enlarged and frequently contains caseous or purulent foci.

The liver does not ordinarily show any changes but when it does such changes are similar to those in the spleen.

The lungs are involved rather frequently and may show first a more or less diffuse gray consolidation affecting a whole lobe or a whole lung; second, disseminated purulent or caseous areas varying in size from a pin head to a pea.

Plague in squirrels is seen as acute cases, subacute cases and residual abscesses.

Plague in ground squirrels must not be confused with the plague like disease of rodents due to *Bacterium tularense* McCoy and Chapin, which has very similar pathological characteristics. This disease is readily transferred to guinea pigs, mice, rabbits, monkeys, and gophers but rats are only moderately susceptible. Lesions in guinea pigs, however, show a striking resemblance to plague. (See Tularaemia.)

Plague in Guinea Pigs.— Plague in guinea pigs is ordinarily seen only after inoculation in the laboratory. There is an area of necrosis at the point of the inoculation. The subcutaneous tissue is thickened and hemorrhagic and surrounded by gelatinous edema and marked injection is present, especially noticeable around the bubo. The glands are enlarged, caseous, hemorrhagic and surrounded by injection and edema. The location of the bubo depends upon the point of inoculation. The spleen is enlarged, dark, friable, and studded with whitish areas about the size of a millet seed. The liver is enlarged and congested.

Susceptibility to Plague of Certain Small Mammals of the United States, Other than Rodents Which Have Been Found Naturally Infected. Laboratory investigations made by McCoy have shown that the following animals are susceptible to plague after inoculation.

Family Sciuridae	Arizona prairie dog (*Cynomys ludovicianua arizonensis*)
	Rock squirrel (*Citellus grammurus*)
	Antelope ground squirrel (*Ammospermosphilus leucurus*)
	Chipmunk (*Callospermophilus chrysodeirus*)
Family Muridae	Eastern desert wood rat (*Neotoma albigula angusticeps*)
	Field mouse of California (*Microtus californicus*)
Family Mustelidae	Weasel (*Putorius xanthogenys*)
Family Geomyidae	Pocket gopher of California (*Thomomys bottae*) very slight susceptibility)
Family Felidae	The Domesticated cat (*Felis domestica*)

Cats naturally infected with plague are occasionally found The disease is usually in a subacute form. Wild rabbits have been found naturally infected with plague in England. Except for the cat, domestic animals seem to be quite resistant to plague infection and only experience local and temporary constitutional effect after feeding on or inoculation with plague material, (pig, calf, goat, sheep, dog, and pigeon).

Laboratory animals including guinea pigs, rabbits, white rats, and monkeys are highly susceptible to plague infection. Guinea pigs and white rats are especially valuable for use in demonstrating plague infection, domestic rats may also be used. It must be remembered that considerable natural immunity may be present in domestic rats. This has been demonstrated by laboratory investigation. Indeed, occasionally a guinea pig naturally immune may be encountered.

Morphology and Cultural Characteristics of Bacillus pestis.—A short thick bacillus with rounded ends, non-motile, gram negative, staining readily with weak aniline dyes more densely at the poles, therefore called bipolar staining. In the tissues it not infrequently appears in the coccoid form. This can be differentiated from a true coccus because it will prove to be gram negative while a coccus is gram positive. Too much importance must not be placed in the morphology and tinctorial reactions of the plague bacillus. Animal inoculation should always be made and usually cultural characteristics should be determined. The appearance and character of the culture should be as follows: (McCoy.):

Agar—Smooth, glistening, round whitish colonies which are found to be sticky when touched with an inoculation needle.

Broth—A scanty surface growth which falls, often in globular masses, when the tube is gently agitated; and a fine flocculent precipitate.

Litmus milk—Generally rendered slightly acid.
Glucose broth—Rendered slightly acid. Gas is not formed.
Lactose broth—Unchanged in reaction. Gas is not formed.
Salt Agar—On 3% salt agar involution forms appear, the bacilli assuming large balloon shape bodies like gigantic cocci, dumb bell and trypanosome-shaped forms.

It is often possible to secure pure cultures from the heart's blood, bubo, spleen, or liver but it is always well to recover the organism by animal inoculation using the cutaneous method. By this is meant shaving the abdomen of the animal over an area of about one inch square, abrading the epthelium very slightly. Suspected material or culture is then rubbed in with dressing forceps. This method has an advantage in that it acts as a filter preventing passage of most microorganisms other than plague bacilli. Guinea pigs inoculated by this method usually die in less than seven days. White rats die a few days earlier. A control pig immunized with 1 cc. of Yersins serum, given at the time of inoculation with the suspected material, should be used.

Another useful method of inoculation is to make a small pocket in the subcutaneous tissue of the abdomen inserting therein a piece of the suspected material or a loop full of culture.

Examination of Rats for Plague.—Rats having been brought to the laboratory properly dipped in kerosene and tagged are stretched on a board, back down and fixed with a tack through each foot. An incision is then made through the skin, in the median line, extending from the submaxillary to the pubic region. Two large skin flaps are then dissected back on each side exposing the cervical, axillary and inguinal regions.

The abdominal muscles are then grasped with a pair of forceps, and with scissors, a large flap is cut from below upward exposing the abdominal viscera. The ribs are then cut through on both sides, thus making another flap which when raised exposes the contents of the thorax. The glandular regions, subcutaneous tissue, spleen, liver, and pleural cavity, should then be examined carefully for evidence of plague.

Count should be made of the number of rats sent to the laboratory, their species and sex; the number pregnant, the number examined and the number found plague infected. For each plague infected rat complete data should be kept as follows:

PLAGUE RAT CARD

Plague rat No

Date
Species
Sex:
No. of fetuses
From:
Condition:
Subcutaneous injection
Lymphatic glands, bubo or other lesions
Liver:
Spleen:
Pleural effusion:
Purulent or caseous foci:
Diagnosis from gross lesions:
Diagnosis from smears:
Cultures:
Inoculation:
Vaccination:
Date suspicous:
Date positive:
Date negative:
Other pathological conditions:

The work should be done in a screened, rat proof room with sewer connections. Examination tables should have a lead lined top sloping towards the middle, with a drain leading into a bucket of disinfectant solution.

Large stone jars of at least 20 gals. capacity may be used to retain inoculated rabbits, guinea pigs and white rats, a screen of cheese cloth to be used as a cover. Inoculated wild rats should be confined in cages placed within jars or garbage cans.

An incinerator should be provided for the disposal of plague infected animals. Others may be placed in metal cans with tight tops and taken to the municipal incinerating plant if there be one.

Methods of Control

In the prevention and control of bubonic plague the great object to be attained is that of placing the environment in such condition that man and rat or its fleas will not come into contact and that conditions are such that the presence of rats will be discouraged. The extermination of rats by the usual means is practically impossible but it is quite possible to reduce the rat population by trapping and poisoning, and to finally build them out of existence, by proper rat proofing procedure, at the same time abolishing all conditions that furnish a harboring, breeding and

feeding place for rats. Rats are killed in a campaign against plague, not only to reduce the rat population, but also to discover plague rats so that foci of infection may be known and stamped out by proper rat proofing operations.

Organization.—To successfully carry on a campaign against plague, proper organization is necessary. This should include a central office force, a laboratory and a field force. In the interests of effective administration, the city should be divided into districts. Each district should be in charge of a Medical Officer who should have under his control the necessary personnel, consisting of inspectors, foremen, trappers and laborers.

At headquarters policies should be adopted and educational measures instituted, statistical information collected and compiled and general supervision maintained over the entire work.

In the laboratory rats sent in are examined for plague to discover foci of infection, post mortems are performed and laboratory diagnoses made of human cases. Identification of rats and flea surveys are also made.

In the field, rats are trapped or poisoned and transmitted to the laboratory. Inspections and reports are made of those places in need of rat proofing, demolition, cleaning up, etc. It is well to have all orders relative to rat proofing and similar requirements emanate from headquarters but the follow up system to determine if orders are being obeyed must be carried on by the district officer. If there are no laws or ordinances under which to act, rat proofing ordinances should be formulated, and promulgated promptly. Enforcement of rat proofing ordinances is frequently difficult and many obstacles may be expected. To rat proof requires money which must come out of the pockets of those against whom an order is issued. It is especially difficult to make them see the necessity of rat proofing when rat plague only is present. Even thinking business men, and city officials object until they realize that without adequate measures their business is placed in jeopardy. Preliminary to issuing rat proofing orders, clear evidence must be procured of the conditions. Photographs are valuable evidence and there should be at least two witnesses. Any case is liable to be protested in court.

Foremen, Trappers, and Laborers.—Each foreman should have under his supervision five laborers or trappers. Each trapper should be provided with 25 cage traps and 50 snap traps.

Trappers should receive a daily wage, plus a bonus for each correctly labelled rat brought in, over a certain number, with an extra bonus for each plague rat caught and sent to the laboratory. The wages paid depend upon standard of wages in the locality.

In addition to trapping in the city, a certain amount of trapping should be done on the outskirts, even extending into rural districts, in an effort to get rats as well as other rodents common to the locality. It is necessary to determine if plague infection has spread to the country animals.

When a plague focus has been found, it is well to start intensive rat eradication operations in at least twelve blocks using the house from which a plague rat is taken as the center. A line of traps and poison should be placed to encircle this area. Beginning at the center, the work of demolishing rat harboring places by tearing up wooden floors, tearing out double walls, cleaning up lumber and rubbish piles and the like followed by adequate rat proofing, should extend toward the periphery as intensive trapping and poisoning is carried on in the surrounding zone extending towards the center.

Rat nests should be treated with insecticide and burned. It is well to spray the ground area with insecticide. An emulsion of equal parts of kerosene and a 5% cresol solution is valuable or an emulsion containing 85 parts of kerosene mixed with 15 parts of hot soap solution, and used in the proportion of 2 parts of the emulsion to 98 parts of water.

Depopulation.—Depopulation is really a logical procedure where it can be carried out. By this means persons are immediately taken away from contact with rats and from fleas and not permitted to return until the area has been put into a rat free condition. While harboring places are being searched for, every effort should be made to kill escaping rats by dogs, clubs and otherwise. It is a good plan to surround the building, buildings, or even entire city blocks with a galvanized iron fence to prevent the escape of rats to adjoining buildings or blocks.

Traps.—Two kinds of traps may be used, snap traps and cage traps. Ordinarily snap traps are more effective, i.e., in the long run there will be more rats collected from snap traps than from cage traps. The latter are large, unhandy to carry and require more attention and are apt to be neglected by the trappers. It is quite possible that equal attention paid to both on the part of the trapper would increase the catch from the cage traps. A variety of bait may

be used, such as bacon, cheese, bread, green vegetables, meat, grain, etc. As a general rule, the choice of bait depends on the character of food supply in the place being trapped. First try baiting the trap with the food most available, that is, in a butcher shop use meat, in a granary use grain, if this is not successful, then use some other kind of bait. Rotation of baits after a trial of each one for two or three days should be practiced. If there is undoubted evidence of rats and yet the first day or two none are caught, do not get discouraged, leave the trap in its place until the rats become accustomed to it. Rats are wary animals and not easily fooled. Cage traps should be placed near rat holes or rat runs, and places where rats are accustomed to feed. It is ordinarily desirable to cover them with gunny sacks, straw or similar material. Snap traps preferably should be placed in the rat run and sprinkled over with a little dust, grain or any material available. Cage traps should be of the larger type, 20 inches in length and the wire should be reinforced so that a rat cannot push its way through by spreading the wires. When after successful trapping operations several days pass without securing any more rats, traps should be moved to new places. One of the most important things for successful trapping is that no food other than bait in the trap should be available, therefore all food should be protected against rats and garbage should be placed in tight cans and properly disposed of. Traps and bait should be handled with gloves.

The British have been successful in catching rats by using a sticky substance consisting of linseed oil and rosin. This is spread over trays with a piece of bait on cardboard placed in the center.

A certain number of live rats should be trapped for laboratory purposes, and in order to determine species and the number of fleas per rat from season to season. There is thus obtained from time to time the approximate degree of flea prevalence a valuable index bearing on the possibilities of spread of the disease. To secure live rats, cage traps must be used as snap traps kill immediately.

Every opportunity should be taken to search for and transmit to the laboratory all rats found dead. It is obvious that during epidemics of plague, large numbers of rats die from infection, thus the chances of finding a plague infected rat among those found dead is much greater than the finding of one among those trapped. It is sometimes possible to recover by animal inoculation plague bacilli

from a plague rat, even though decomposition is well advanced and the characteristic signs of plague have disappeared.

Guinea Pig "Controls" "Sentinel" or "Barometer."– The use of guinea pigs to detect plague infection in a house has been practiced on a number of occasions. Several guinea pigs in cages are placed in a suspected room or house. These animals will attract fleas and in the presence of plague infection may develop plague. Creel has suggested that more wide spread use be made of this procedure, in that the guinea pigs be released in one or more houses in each city block in a hope that they may furnish an index to the distribution of the disease. Houses known to harbor rats should be chosen and if, after a week's trial, no infection develops among the guinea pigs in the block under observation they should be moved to other parts of the city. In this way it might be possible to determine foci of rat infection in advance of the slower method of trapping and examining. Incidentally by attracting the fleas guinea pigs serve to protect human beings.

Poisoning.—Poisons are of doubtful value as aids to rat destruction. The number of rats found dead following intensive poisoning operations is ordinarily not increased. It is possible that poisoned rats may seek the sewers where they die and are washed out through sewer outlets unnoticed. It is also possible that poisons may only serve to drive the rats away to other parts. This is not desirable.

Poisons must be laid with great care, well out of reach of children and domestic animals. Arsenic does not deteriorate and therefore, remains poisonous for indefinite periods. Phosphorus deteriorates with age. It is also inflammable, and must be placed away from inflammable material.

A few formulas for rat poisons:

1. Rice or corn meal.	5 lbs.
Commercial arsenic	1 lb.
Mix thoroughly and boil until cooked.	
2. Sugar	3 lbs.
Oatmeal	13 lbs.
Commercial arsenic.	4 lbs.
Mix thoroughly.	
3. Ground rusty bacon	4 lbs.
Ground corn soaked over night in a solution of syrup and water	3 lbs.
Commercial arsenic	½ lb.
Mix thoroughly.	

Phosphorus may be used by mixing crude phosphorus in the proportion of 5%, with cheese and sugar heated together to the

consistency of syrup. The phosphorus is added after the syrup has been taken from the fire and cooling has begun.

Strychnine has been found useful in the destruction of ground squirrels. Wheat should be soaked over night in water. The excess of water should then be poured off and the grain soaked in a hot glucose solution containing $\frac{1}{10}$th. of 1% of strychnine sulphate. Stir well and then allow to dry in shallow pans over a slow fire or by exposure to the sun. Cyanide of potassium or sodium may be added in the proportion of $\frac{1}{2}$ of 1%.

Bacterial Virus.—The use of a bacterial virus such as *Bacillus typhi murium* has not been successful in even reducing a rat population. There is no disease with which rats can be infected that will exterminate them. If there were, bubonic plague itself would probably do it. The use of a bacterial virus is futile.

Rat Proofing

In view of the fact that total eradication of the rat by the usual methods is impracticable, rat proofing becomes a logical and a certain method for the control of bubonic plague. It has two chief purposes. The first is to prevent contact between rat and man; the second is to eliminate the breeding and feeding places of rats. The methods used in rat proofing vary somewhat depending upon the case. Perhaps the simplest form of rat proofing is by elevation by which is meant the elevation of premises at least 2 feet above the ground. The space underneath may be left uninclosed and unobstructed so that free access to cats and dogs may be had. There must be no accumulations of rubbish to furnish harbors for rats. If the space is to be inclosed, walls should be of concrete, or of brick set in cement either to extend at least two feet into the ground. Openings provided for ventilation must be well screened with heavy iron wire having a mesh not exceeding one-half inch. Walls must be flush with the floor. Lumber and material about the yard which cannot be destroyed, should be elevated at least two feet from the ground.

Basements and cellars should be of concrete or of cement, reinforced by heavy wire screening. Concrete is by far the best rat proofing material. It should be made of a standard cement, clean sharp sand and stones in the proportion of 1:2:5. Walls should be at least 6 inches thick and floors 3 inches thick with $\frac{1}{2}$ inch of cement laid on the surface.

Double walls should be avoided, or the space between should be filled above and below to prevent the entrance of rats, and a wire mesh should extend upward back of the base-board. Basement ceilings should remain unsealed.

Wooden floors, unless laid directly upon concrete, should be made of two layers of tongue and groove boards, separated by a layer of wire cloth with a mesh of about ½ inch. Doors, basement windows, roof hatches, and the like should be well fitting. Ventilation louvers, conduit openings, and openings for the entrance of piping should be filled by cement or screened with ½ inch mesh wire cloth, as the case may be.

Rats are frequently harbored under pavements. These should receive attention. Wooden walks are especially objectionable.

Chicken Coops.—Chickens and pigs should not be kept within the city limits. It is permissible to make an exception in the case of chickens when chicken coops are properly constructed. They should be surrounded by a concrete wall extending into the ground at least two feet, and one foot above. The top and sides of the coop should then be enclosed by wire netting of ½ inch mesh.

Stables. Stables should have rat proof floors, i.e. concrete floors preferably. Cribs should be built with a flareup from below outward, and rendered rat-proof by a covering of zinc.

City Sewers. Rats harbor in city sewers in large numbers. They enter and leave mainly by way of the catch basin, but they may go through house sewer systems, burrowing along side the house sewer. Catch basins should be made rat-proof by having smooth vertical sides, with the opening from the street at least three feet above the opening into the sewer. Traps in the sewer should be done away with, as well as basins for the collection of silt. There should be a smooth round bottom leading directly into the sewer pipe. This is the modern idea of the catch basin. Incidentally it does away with any collection of water at the bottom where mosquitoes may, and in fact, frequently do breed. It will also save money to the city, in that, cleaning of such a catch basin is unnecessary.

Wharves. Wharves should be of rat proof construction preferably of concrete, with no harboring places for rats above or below. They may be provided with rat proof compounds, into which cargo may be unloaded.

Freight cars also require attention. They should be repaired so that there are no openings for the entrance of rats, and when left standing on track overnight, partly or wholly loaded, should be closed.

Ships.—Ships should be fumigated regularly to kill rats and while along side a wharf or dock should have rat funnels on all lines. The gang-way should be hoisted at night and the vessel should be fended off from the dock at least six feet. This may be done by means of a raft floated between the ship and the wharf piling.

Garbage.—Proper care of household garbage is important. It should be kept in a galvanized iron can with tight fitting cover, and should be collected at least once a week, and disposed of in an approved manner.

Infected Buildings.—Occupants should be removed and the building fumigated; fumigation to be followed by a thorough renovating to place the premises in a rat-free and rat proof condition. Double walls should be torn out, planking must be torn up, and the ground beneath broken to break up rat burrows, then soaked with kerosene or a kerosene emulsion, and concreted.

The cessation of human plague is no criterion that plague has disappeared. It is only when no plague rats have been found for at least one year, during which period they have been trapped and examined conscientiously, that one can believe that the infection has been stamped out. Even then, it is unwise to discontinue rat proofing, as rat plague may only be quiescent, or the same factors which permitted the entrance of a plague rat may be still operative, and reinfection may occur. Rat proofing measures should be carried out at all times, with or without the presence of plague. This is a preventative measure well worth the cost.

It is not unlikely that after intensive work to destroy rats, not more than 50% of the rat population is actually eliminated. It would seem that as the activities progress, the rats that remain have a much easier time in securing food, and it may be that with their gradual extermination, breeding occurs more frequently in a natural effort to resist extermination of the species.

After one has carried on an intensive campaign of trapping and poisoning, it has been suggested that the repression of rats can be accomplished quicker and with more permanent results, by sexual selection—destruction of females only, permitting the males to go

free. In this way there is brought about a natural but gradual extermination of the species.

PNEUMONIC PLAGUE

Pneumonic plague is a form of pneumonia due to the plague bacillus. It is a highly fatal disease resulting in a case fatality rate of practically 100%. Epidemics of pneumonic plague are not uncommon in North China during the winter months when people are huddled within their houses without ventilation and with a high degree of relative humidity. Such epidemics seem to have had their beginning, in a case of bubonic plague contracted from handling a plague infected marmot. It is curious that a small outbreak of pneumonic plague in Oakland, California, in 1919 had its origin in a case of human bubonic plague contracted from a plague infected ground squirrel. Pneumonic involvement in naturally infected ground squirrels is a common pathological condition.

Cases of primary pneumonic plague are rare in warm weather. Low temperatures, shut up houses and a high degree of relative humidity seem to be necessary. In a warm dry atmosphere the droplets expelled from the mouth and nose dry rapidly and plague bacillus is very short lived. In a close humid atmosphere in closed unheated houses the danger of spread is great.

Primary pneumonic plague is transmitted directly from person to person as in other diseases of the respiratory type and does not depend for its occurrence upon infection in rats or the presence of fleas.

A Guide for Formulating a Rat Proofing Ordinance

The following outline for a Rat Proofing Ordinance has been suggested by the U. S. Public Health Service (Public Health Reports, November 5, 1920). Like all model ordinances it may require some modification in order to adapt it to local conditions.

Ordinance No. ——

An ordinance requiring every building, house, outhouse, or other superstructure hereinafter to be erected in the city of ——— to be rat-proofed.

Be it ordained by the city council of ———.

SECTION 1. That every building, house, outhouse, or other superstructure of any and every character whatsoever hereafter erected in the city of ——— shall be rat-proofed in the manner hereinafter provided.

SEC. 2. It shall be unlawful for any person to construct any building, house, outhouse, or other superstructure within the corporate limits of the city of ——— unless the same shall be rat-proofed as hereinafter provided.

SEC. 3. For the purpose of rat-proofing, all buildings, houses, outhouses, or other superstructures, except stables, shall be divided into two classes, to wit: Class A and Class B.

SEC. 4. That every restaurant and restaurant kitchen, hotel and hotel kitchen, boarding-house kitchen, slaughterhouse, packing house, bakery, every place where foodstuffs or refreshments of either solid or liquid form are manufactured, stored, kept, sold, prepared, or offered for sale, every warehouse, freight shed; every place wherein live or dressed poultry, game, animals, or birds are sold, stored, or kept for sale; every junk shop, chicken, or poultry house, pen or inclosure, and every place where hides are kept, handled or stored, shall be rat-proofed in the manner provided for hereinafter as Class A.

All other buildings, outhouses, and superstructures, except stables, not hereinbefore specified as Class A, and all buildings used exclusively for residential purposes, shall be rat-proofed in the manner provided for hereinafter as Class B; provided that the owner of any building, residence, outhouse, or other superstructure in Class B, may, if he so selects, rat-proof the same in the manner provided for in Class A.

"Foodstuffs," as used in this ordinance, is hereby defined to mean flour, flour products, animals and animal products, produce, groceries, cereals, grain and the products of cereals and grain, poultry and its products, game, birds, fish, vegetables, fruits, milk, cream, and the products from milk or cream, ice cream, liquid refreshments of every character, or any combination of any one or more of the foregoing.

SEC. 5. That the construction and material used in rat-proofing shall conform to the building ordinances of the city of ———, except, and only in so far, as the same be modified herein.

SEC. 6. *Class A.* The ground floor of every building, outhouse or other superstructure in Class A shall be of concrete, which concrete shall be not less than three inches thick and overlaid with a top dressing of cement, mosaic, tiling, or other material impermeable to rats, and such floor shall rest, without any intervening space between, upon the ground; said floor shall extend, and be hermetically sealed to, walls surrounding said floor, which walls shall be of concrete, or of stone or brick laid in cement mortar, and each wall to be not less than six inches thick, and shall extend into and below the surface of the surrounding ground not less than two (2) feet, and shall extend upwards not less than twelve (12) inches above the surface of said floor.

SEC. 7. *Class B.* All buildings, outhouses, and other superstructures of Class B, shall be set upon pillars or underpinnings of concrete, or of stone or brick laid in cement mortar, such pillars or underpinnings to be not less than eighteen (18) inches high, except where the building, outhouse, or superstructure is more than thirty (30) feet in width, the height to be measured from the ground level to the top of said pillars or underpinnings, and the intervening space between the building and the ground level to be open on at least three sides and to be free from all rubbish and other rat-harboring material, or may

be rat proofed by constructing at the margin of the ground area of said building a sustaining wall of concrete, or of brick or stone laid in cement mortar, such wall to extend into and below the surface of the ground at least two (2) feet and to meet the floor of the building above closely without any intervening space. Such walls shall be at least six (6) inches thick and shall extend entirely around the said building: *Provided*, That said walls may be built with openings therein for ventilation only: *And provided further*, That such openings for ventilation may be of such size as the owner may elect and shall be securely screened with metallic gratings having openings between the bars of said gratings of not more than one-half (½) inch, or with a wire mesh of not less than 12 gauge, having openings between the wires of said mesh of not more than one-half (½) inch and the whole so constructed and closed as to prevent the entrance of rats beneath such buildings.

Provided, That when the owner of any building, outhouse, or other superstructure, which is more than thirty (30) feet in width and which is herein classified as Class B, shall elect to rat-proof same by elevating same, that he shall elevate same to a height in excess of eighteen (18) inches to wit: that for every additional ten (10) feet or fraction thereof in excess of thirty (30) feet in width, the building outhouse, or other superstructure shall be elevated an additional six (6) inches.

Sec. 8. That in any case where, under the provisions of this ordinance, any building, outhouse, or superstructure is required to be rat-proofed as Class A, and the said building or outhouse or superstructure is used in part for residential purposes, and the part used as a residence is effectively separated from the part falling within Class A by permanently and effectively closing all openings above and below the ground floor or by constructing a new wall, and in either case the whole, in such manner as to make such wall wholly and continuously in its entirety without doorways, windows, or other openings between the part used as a residence and that used for such purpose as makes it fall within Class A, then in such case, and for rat-proofing purposes only, the said building will, after such separation and closure of the openings, or by the construction of such new wall, be deemed to be two buildings, and that the part used exclusively for residential purposes may be rat-proofed in the manner provided for as a Class B building, and the remaining part of said building shall be rat-proofed in the manner provided for as Class A buildings.

Sec. 9. *Stables.* Every building hereafter constructed and used for stabling any horse, cow, mule, or any other animal or animals shall be constructed as in this section provided.

Walls. The sustaining walls of such building shall be constructed of concrete, or of brick or stone laid in cement mortar, and shall be not less than six (6) inches thick and shall extend into and below the surface of the surrounding ground not less than two (2) feet, and shall extend above the ground a sufficient height to be not less than one (1) foot above the floor level. All openings in such foundation wall shall be covered with metal grating having openings not greater than one-half (½) inch between the gratings.

Floors. The floors of stables and stalls shall be of concrete, not less than three (3) inches thick, upon which shall be laid a dressing not less than one-half

($\frac{1}{2}$) inch thick, of cement, or of stone laid in cement mortar in such way as to prevent ingress or egress of rats, and such floors to have a slope of one-eighth ($\frac{1}{8}$) inch per foot to the gutter drains hereinafter provided for.

It shall be unlawful to install or construct or permit to be installed or constructed any double wall, double floor, or double ceiling with open spaces therein in any building or superstructure used or intended to be used as a stable.

Stalls.—Floors of stalls may be of planking, fitting together tightly to the concrete floor, or elevated not more than one-half ($\frac{1}{2}$) inch from the concrete floor and so constructed as to be easily removed. Such removable planking shall be raised at least once a week and the said planking and the concrete floor beneath thoroughly cleansed.

Gutters.—Semicircular or V-shaped gutter drains shall be constructed in such stables in such manner that the gutter shall be placed so as to receive all liquid matter from each stall and to carry it from said stable.

Manure.—All manure in and about all stables shall be removed therefrom at least once a week, and the same shall be removed entirely from the premises, unless scattered as fertilizer or otherwise utilized, so as not to furnish food for and attract rats.

Mangers.—Each manger shall be constructed so that the sides shall have an inward slope from top to bottom of two (2) inches and, if made of wood, shall be covered with tin or zinc and shall be at least eighteen (18) inches deep to avoid the spilling of food.

Feed Bins.—All feed bins shall be constructed of cement, stone, metal, or wood, and with close-fitting doors. If constructed of wood, the bin shall be lined or covered with metal and the whole so constructed as to prevent the ingress or egress of rats.

All grain, malt, and other animal food, except hay, stored or kept in any stable must be kept in such feed bins. Said feed bins must be closed at all times, except when momentarily opened to take feed therefrom, or when the same are being filled. No feed shall be scattered about such bin or stable, and all such feed found on the floor or in a stall of such stable shall be removed daily with the manure. No foodstuffs intended for or susceptible of human consumption shall be kept or stored in any stable or any other place where animals are kept.

Sec. 10. That all accidental and unnecessary spaces and holes, ventilators, and openings other than doors and windows, in every building, outhouse, and other superstructure hereafter erected in the city of ——— shall be closed with cement mortar or other material impervious to rats or screened with wire, having not more than one-half ($\frac{1}{2}$) inch mesh, as the case may require, or be closed with galvanized iron; and all wall spaces shall be closed with cement mortar or other material impervious to rats, which closure shall extend the full thickness of the wall and shall extend upward at least twelve (12) inches above the floor level, and the whole done in such manner as to prevent the ingress or egress of rats: *Provided*, That in all buildings, outhouses, and other superstructures of Class A, and in all stables where there are any spaces in walls between the wall proper and the covering of same, or in ceilings between the ceiling and the floor or other ceiling covering, both said spaces shall be elimi-

nated by the removal of said covering or effectively blocked or closed so as to prevent the ingress or egress of rats.

SEC. 11. That all premises, improved and unimproved, on all open lots, areas, streets, sidewalks, alleys, in the city of ——— shall be kept clean and free from all rubbish, as well as loose material that might serve as harborage for rats; and all lumber, boxes, barrels, and loose iron, as well as material that may be permitted to remain thereon and that may be used as a harborage for rats shall be placed on supports and elevated not less than two (2) feet from the ground, with a clear intervening space beneath to prevent the harboring of rats.

SEC. 12. That all planking and plank walks on and in the yards, alleyways, streets, sidewalks, or other open areas shall be removed and replaced with concrete, or with brick or stone laid in cement or gravel, or the ground left bare: *Provided*, That nothing herein shall apply to streets or other public places paved with wooden blocks.

SEC. 13. It shall be lawful to install a cellar or basement in any building, outhouse, or superstructure hereafter erected in the city of ———, but in every such case the cellar or basement shall be inclosed within solid walls of concrete, or of stone or brick laid in cement mortar, or tiles of not less than nine (9) inches, with no openings below ground save for plumbing, and such openings securely protected against the ingress or egress of rats, and with no openings above ground, except doors and such windows or light or air vents as will be susceptible of being screened with wire screens of not exceeding one-half (½) inch mesh; and such cellars or basements shall have the floor constructed of concrete or stone at least three (3) inches thick, or of brick laid in cement mortar, and such floor shall be hermetically sealed to the walls of such cellar or basement. The doors or trapdoors for entry to such cellar or basement shall be securely fitted in such manner as to prevent, when closed, the ingress or egress of rats.

SEC. 14. No permit shall be granted by the building inspector (or other official whose duty it is to grant building permits) for the reconstruction, alteration, or repair of any building, outhouse, or other superstructure in the city of ——— unless provisions shall be made in the plans therefor for the proper rat-proofing of such building or superstructure in substantial compliance with the provisions of this ordinance when, in the judgment of the building inspector (or other official whose duty it is to grant building permits) it is practicable, desirable, or necessary that such rat-proofing be done; but in no event shall such reconstruction, alteration, or repair be permitted without full compliance with all the provisions of this ordinance, where the cost and expense of such reconstruction, alteration, or repair shall, in the opinion of the building inspector (or other official whose duty it is to issue building permits) equal or exceed forty (40) per cent of the value of the structure sought to be reconstructed, altered, or repaired.

SEC. 15. That the word person as used in this ordinance shall be taken to mean and include firms, copartnerships, corporations, and persons of both sexes.

SEC. 16. That any ordinance or part of ordinance in conflict with the provisions of this ordinance is hereby repealed to the extent of such conflict.

SEC. 17. Should any part of this ordinance be declared invalid, the remaining portions shall not thereupon be invalidated, but shall remain in full force and effect.

SEC. 18. *Penalty.*—Any person violating any of the provisions of this ordinance shall be punished by fine not to exceed ——— or by imprisonment not to exceed ——— or by such fine and imprisonment.

SEC. 19. *Emergency.*—(The clause declaring an emergency to be inserted if necessary under local laws.)

With regard to the above model ordinance certain changes have been suggested as follows:

That the ordinance be so worded that its provisions shall apply to the rat-proofing of buildings already constructed when such a procedure shall be deemed necessary, as well as to buildings to be erected in the future.

Sec. 2. "It shall be unlawful for any person to *maintain* or construct any building etc."

Sec. 6. Specify that the top dressing of cement be not less than one-half inch in thickness.

Sec. 7. Permit the use of ordinary mortar in the construction of brick underpinning; also permit the use of wooden posts for underpinning.

Sec. 10. Specify that the wire screening of not more that one-half inch mesh shall be not less than 14 inch gauge.

Sec. 13. Specify that the walls of basements whether of brick, stone, concrete or tile, shall be not less than nine inches thick. (Six inches is sufficient for rat-proofing purposes but here strength of construction must be taken into consideration.) Specify that the one-half inch wire screen shall be of not less than 14 inch gauge.

In general, for rat-proofing purposes, walls should be not less than six inches thick and floors not less than three and one-half inches thick. Brick should be laid on one-half inch of cement and should have a top dressing of cement of not less than one-half inch in thickness.

CHAPTER XXXIII

TYPHUS FEVER

Causative Agent.—Typhus fever is believed to be due to a micro-organism known as *Rickettsia prowazeki.* It is pathogenic for monkeys and guinea pigs.

Source of Infection.—The blood of patients having typhus fever.

Period of Communicability.—During the febrile attack, especially in the first ten days of the disease.

Mode of Transmission.—The disease can be contracted through inoculation of infected blood. In nature transmission is brought about through the agency of the body louse *(Pediculus corporis)* commonly, and the head louse (*Pediculus humanus*) occasionally. It may be, that when transmitted by the latter, the disease runs a milder course.

Period of Incubation.—5 to 20 days. Usually about 12 days.

Epidemiology.—Typhus fever has ravaged armies in the field from time immemorial. Older descriptions of the disease undoubtedly combine descriptions of typhoid fever, for it was not until the year 1837 that the differences between typhus fever and typhoid were clearly recognized. There has probably not been a single war in which typhus fever has failed to take its toll, from both the military and the civil population. The disease was nearly always present where there was overcrowding and filth, and it has been called camp fever, jail fever and ship fever.

During the world war typhus fever was prevalent in Serbia, Austria-Hungary, Germany, and Russia, Serbia suffered most severely, and it has been estimated that there were 135,000 victims to the disease. It was rare on the Western front.

Typhus fever is endemic in some of the larger European cities and occasional cases are seen in the United States, where it passes under the name of Brill's disease. It occurs during the colder months of the year, subsiding upon the advent of warm weather. Except in high altitudes, it is practically unknown in the Tropics. The body louse, which is the most important intermediary host, does not seem to survive under tropical conditions. Furthermore in sum-

mer clothing is changed more frequently and is made mostly of cotton goods. The disease is common in the higher altitudes of Mexcio where it is known as *tabardillo*.

It attacks all ages and both sexes and is associated with cold weather, overcrowding, filth and squalor, — conditions under which body lice thrive.

Those infested with vermin are especially liable to attack although a high percentage of doctors and nurses in attendance upon typhus fever patients may become infected.

One attack confers lasting immunity. Second attacks are very rare.

In children typhus fever has a low mortality. Passed middle age the case fatality rate may be as high as 40 or 50%. The average rate is about 12 to 20%.

The bite of one infected louse is sufficient to produce the disease. The infective agent circulating in the blood is taken into the stomach of the louse at the time of biting and is then transferred to the blood of another individual. The exact method of transmission is unknown, and it may be purely mechanical. The feces of the louse have been demonstrated to contain the causative agent. It would seem, however, that several days (8 to 9) must elapse before the louse can transmit infection, and that it probably remains infective for the rest of its life. It is therefore not improbable that there is a definite life cycle, part of which is spent in the body of the louse. The microorganisms invade the cells of the lining of the gut of the louse. They are intracellular. A similar microorganism is the cause of trench fever which is also transmitted by lice. Here however the microorganisms are extracellar and there is little swelling of the cells.

When infected blood is inoculated into a monkey intraperitoneally or intravenously there follows, after an incubation of from 5 to 14 days, a rapid rise of temperature usually reaching a maximum of about 41°C. in 36 to 48 hours. At the end of the febrile period the temperature may decline gradually but more usually falls by crisis. The rise of temperature is practically the only definite index that infection has taken place. In guinea pigs there is a reaction in the genitalia of male animals similar but milder in character to that seen in pigs infected with Rocky Mountain spotted fever. The reaction is characterized by swelling and petechial hemorrhages into the scrotum, testicles and epididymus and their envelopes, due to lesions of the blood vessels. The lesions produced by typhus fever are micro-

scopic. There is a proliferation and swelling of the endothelial cells of the blood vessels, followed by a degeneration. Minute thrombi and small areas of necrosis may result. The causative agent may be demonstrated in the endothelial cells.

Recognition of the Disease. Prodomal symptoms may be present, but frequently the disease develops suddenly with chills, vomiting, epistaxis, pain in the head, back, and limbs. The headache is severe and persistent, the face is flushed and the conjunctivae injected. Cough is present and prostration and delirium come on early. The fever rises rapidly to 103°F. more or less, and by the fifth day may reach 105 degrees, remaining high with slight daily remissions for about two weeks and ending characteristically by crisis. Leucocytosis is present. The eruption appears on the third to fourth or fifth day, first on the upper part of the chest and later on the arms, abdomen, and legs. The face is ordinarily free. The rash at first resembles the rose spots of typhoid fever, but is more profuse and becomes petechial in character. As the disease advances prostration becomes profound and the nervous symptoms more pronounced. Coma vigil is present with subsultus tendinum. In favorable cases there is a rapid termination. Broncho-pneumonia may be a complication. Mild cases of typhus fever occur during epidemics and a correct diagnosis may be difficult. Brill's disease is typhus fever in a mild form. Mild cases may be confused with typhoid fever or in children especially paratyphoid. The sudden onset, character of the rash, rapid termination, early prostration and brain symptoms may be of value in differential diagnosis. However it must be kept in mind that in the milder forms of typhus the rash may not be so profuse, prostration and brain symptoms may not be pronounced and the disease may end by lysis rather than by crisis. The presence of lice, especially in patients from the lower strata of society, should make one suspicious. The results of the Widal reaction and blood cultures are important. Confusion may also arise in the differential diagnosis between typhus fever and influenza, smallpox, cerebrospinal fever, measles and Rocky Mountain spotted fever.

The Weil-Felix reaction is an important laboratory aid in the diagnosis. This is not a specific reaction as it depends upon the presence of a proteus-like microorganism isolated from the urine or blood of typhus fever patients in 1915 by Weil and Felix, which organism does not seem to be etiologically connected with the disease. They have designated the strain X_2 and X_{19}.

To perform the test use a fresh grown agar culture and suspend in 1.5 cc. of salt solution. Test with the serum of the suspected case in dilutions of 1:25 and 1:50. In cases of typhus fever the agglutination titre should rise from 1:25 on the sixth day to 1:200 or 1:500 or higher on the 12th day. If the agglutination titre does not rise as indicated, typhus fever can usually be excluded. The reaction appears during the first week and is at its height during the second week and during convalescence.

Methods of Control.—The disease should be recognized as early as possible by the clinical symptoms, the presence of lice, the social status of the patient etc.

The patient should be isolated in a vermin free room and the hair should be clipped from the head, body and pubic region. The clippings should be destroyed by burning. The body should then be washed with soap and water followed by kerosene or the kerosene jelly may be used. The head should also be treated.

Attendants should wear vermin proof clothing.

Exposed susceptibles should be quarantined for 14 days from date of last exposure.

Clothing should be treated to destroy vermin and rooms should be kept vermin free.

When there is evidence of louse infestation persons coming from infected areas should have the body and clothing subjected to a delousing process.

There is no method for producing artificial immunity.

For delousing methods see Page 156.

CHAPTER XXXIV

TRENCH FEVER

Causative Agent.—Trench fever is due to a resistant filterable virus which is present in the blood plasma of patients having the disease. This virus is resistant to drying and is killed at a temperature of 70 degrees C., moist heat, for 30 minutes. A microorganism—*Rickettsia quintana*—has been described as the cause.

Method of Transmission.—The disease is transmitted in nature by the *Pediculus corporis.*

Period of Communicability.—Throughout the course of the disease. More communicable during the first and second day.

Period of Incubation.—14 to 30 days.

Epidemiology.—Trench fever is common among armies in the trenches and is the cause of much disability among troops and a great lessening of man power, although it is not important as a cause of death.

The exact way in which the louse transmits the disease is not known, except that it is through the bite. The insect need not remain long on the body to infect. There is some evidence that a definite life cycle takes place within the body of the louse. The virus may also be present in the feces of the louse, and it is possible that excrement may at times also act as the infecting agent by being rubbed into the wound made at the time of biting. The virus is also present in the sputum, feces and urine of the patient.

Recognition of the Disease.—Sudden onset with headache and pains in the legs and back. Post orbital pain particularly when eyes are moved; dizziness; nystagmus on turning eyes competely sideways; injection of conjunctivae and sharp rise of temperature to 103 degrees or 104 degrees F. which in one half the cases subsequently assumes a relapsing character. Three types of the fever exist; a short attack lasting about a week with sometimes a single short rise after a few days; a more prolonged initial fever which may last for 6 or 7 weeks with relapses not distinctly marked; more commonly a fever which relapses with more or less definite normal

intervals, lasting from 5 to 7 days. Variations from these types are not uncommon.

The spleen is enlarged; small erythematous spots are present in 70 to 80% of the cases on the chest, back and abdomen. They are pink in color and disappear on pressure; often disappear in less than 24 hours; in numbers they vary from several to one or two hundred. The time of their appearance not constant. The rash may be distinctly papular.

The urine may show a trace of albumen. The leucocyte count is variable. Frequently there is a leucocytosis but at times the blood is normal or there may be leucopenia.

The number of relapses varies, 3 to five periods are common. Some attacks have 6 to seven relapses.

Recovery usually occurs in from 5 to 6 weeks.

Methods of Control.— Success in prevention lies in the destruction of lice. (See page 156.) A temperature which will kill lice is not high enough to destroy the virus. This probably has little significance as under natural conditions it is lice that transmit the virus to man. However the sputum, urine and feces of the patient should be sterilized.

CHAPTER XXXV

RELAPSING FEVER

Causative Agent.—Relapsing fever is due to a protozoon parasite belonging to the Proflagellata and to the Genus *Borrelia.* The Spirochaetes of relapsing fever vary somewhat in their specific characteristics depending upon the geographical location of the disease.

Method of Transmission.—Relapsing fevers may be divided into two groups, depending upon whether they are louse borne or tick borne. The louse borne relapsing fevers include the European, North African, the Indian and the North American. The tick borne relapsing fevers include the African, the Persian and the Central and South American.

Relapsing Fever	Causative Agent	Intermediate Host
North American	*B. novyi*	Lice
European	*B. recurrentis*	Lice and bed bugs
Indian	*B. carteri*	*Pediculus corporis* *Pediculus humanus*
North African	*B. berbera*	*Pediculus corporis* *Pediculus humanus*
East, West and South Africa	*B. duttoni*	*Ornithodoros moubata*
Persian	*B. persica*	*Ornithodoros savignyi*
South American	*B. novyi*	*Ornithodoros turicata*
Panama	*B. novyi*	*Ornithodoros talaje*

Period of Incubation.—7 to 10 days.

Epidemiology.—In the case of lice, spirochaetes enter the body cavity through the stomach wall. This takes place between the second and eighth day. Infection results not from the bite, but from crushing the louse and rubbing the contents of the body cavity into the wound made at the time of biting. Lice may be said to be capable of transmitting the infective agent during two periods; first, just after inbibing infected blood, and again after two or more days when the spirochaetes enter the body cavity. After the sixth day their infectivity becomes less and less. It has been shown that infection may be transmitted to the progeny.

In the case of ticks, the spirochetes are taken into the stomach from the circulating blood, pass through the stomach walls and into the body cavity, finding their way to the ovary, the eggs, the malpighian tubules and coxal glands. The disease is not transmitted during the act of biting, but results from scratching into the wound made at the time of biting, the discharges from the malpighian tubules or coxal glands. Infection is transmitted to the progeny, so that the immature ticks may transmit the disease. *Ornithodoros moubata* is the intermediate host of *Borrelia duttoni.* It infests houses especially rest houses along the routes of travel, living by day hidden within the cracks and crevices in walls and floors where it also lays its eggs, coming out at night to bite. About 100 eggs are laid and from these fully formed nymphs emerge, the larval stage being spent within the egg. The nymphs may transmit the disease as the spirochete is transmitted by the female to her progeny. Both adult males and females transmit the infecting agent. The act of biting occupies about one hour. Like the bedbug they do not wander far of their own accord but may be carried in bundles of clothing. The other ticks transmitting the disease are somewhat similar in their habits. Relapsing fever frequently attacks children in severe form. One attack of relapsing fever conveys some immunity in that older persons who have had the disease in childhood may suffer from mild attacks and thus serve as carriers by harboring the spirochetes in the circulating blood. The relapse so characteristic of the disease is caused by those spirochetes that have resisted the action of antibodies.

Relapsing fever is more or less common in many parts of Africa Asia, Europe, etc. and is occasionally present in North, Central and South America. Epidemics of relapsing fever are not infrequently associated with epidemics of typhus fever, both being louse borne diseases.

The case fatality rate is 5% to 20%.

Recognition of the Disease.—The disease is characterized by a sequence of several febrile periods lasting about 4 days separated by afebrile periods which last from 4 to 8 days, although these vary depending upon the degree of immunity conferred by a previous attack or by the particular species of spirochete.

The fever rises rapidly to about 104°F. continues high for 3 or 4 days and drops by crisis to be followed by the period of apyrexia during which the patient feels much better. The crisis may be

accompanied by symptoms of collapse, sweating, great prostration and cardiac weakness. Other symptoms are severe headache with pains in back and limbs, nausea and vomiting, absence of delirium, accelerated pulse, precordial distress, cough, tenderness and moderate enlargement of spleen, tenderness over the liver, jaundice and polymorphonuclear leucocytosis.

The most important diagnostic feature is of course the presence of spirochetes in the circulating blood during the febrile attack. They are few in numbers or absent during the afebrile period.

The disease may be confused with malaria, dengue, smallpox.

Salvarsan and neosalvarsan are specific.

Methods of Control.—Destruction of the insect hosts would seem to be logical. This is a difficult accomplishment. In many places where relapsing fever is common, the natives are very indifferent and their cooperation hard to secure. In the tick borne relapsing fevers of Africa, white travelers should avoid native rest houses and should sleep in hammocks or beds isolated so that ticks can not crawl up the legs. The louse borne infections require delousing similar to methods of combatting typhus fever.

CHAPTER XXXVI

ROCKY MOUNTAIN SPOTTED FEVER

Causative Agent.—Unknown. Possibly a Rickettsia-like microorganism which Wolbach has named *Dermacentroxenus rickettsi*. A non-filterable virus, pathogenic for man, monkeys, guinea pigs and white rats, and at least six varieties of the small wild rodents found in the Rocky Mountain region. Larger domestic animals, like sheep and cattle, seem to be immune.

The virus dies within a few days outside of the animal body or the arthropod host. It is destroyed by grinding and loses its ability to infect after 15 days on ice, after thirty minutes exposure to a temperature of 50 degrees C., and within one and two days after complete dessication.

Source of Infection.—The blood of infected animals; infection occurs only by inoculation. In nature this is brought about through the bite of a tick, usually *Dermacentor andersoni*, or the rabbit tick *Haemaphysalis leporis-palustris*, both of which are common in the locality in which the disease occurs. Experimentally other ticks have been shown to be capable of transmitting infection. The tick remains infected throughout its life and the female can transmit the virus to her progeny. Adult ticks, both male and female, larvae and nymphs are capable of transmitting the infection after feeding on infected blood, and the infection is passed on from one stage to the other.

Incubation Period.—This is variable, it may be as long as 12 days, usually four to seven days.

Epidemiology.—In nature the virus is probably carried by small wild rodents and from this source ticks become infected. Under experimental conditions the virus may be kept alive by passage through guinea pigs. 0.5 to 5.0 cc. of infected defibrinated blood, blood serum or corpuscles may be inoculated subcutaneously or intraperitoneally. After a period of incubation of from two to five days, a rise of temperature ensues reaching its height on the fifth to seventh day when swelling and oedema of the scrotum and testicles develop. Vulvar changes may occur in the female. The spleen is large

and congested. The soles of the feet, and ears are congested and macules may be observed on the body. Emaciation is rapid and death usually occurs after a week's illness. If death does not ensue recovery is slow, and may be accompanied by sloughing of the scrotum and loss of the ears. Microscopical lesions are found in the bloodvessels, similar to those seen in typhus fever.

The disease has been transmitted to laboratory animals by allowing them to be bitten by ticks which have fed on the blood of infected animals.

Rocky Mountain Spotted Fever occurs in the Rocky Mountain and Pacific States east of the Coast Range mountains. It has been reported from California, Oregon, Washington, Montana, Idaho, Nevada, Utah, Wyoming, Colorado, and Alaska. In the Bitter Root Valley of Montana the disease is limited to the western side of the Valley.

The disease attacks both sexes and all ages. One attack confers lasting immunity.

The great majority of cases occur between the opening of spring and midsummer, a few are contracted as late as August.

The Rocky Mountain fever tick is rural in its distribution and man becomes infected only by accident. Those whose occupations take them into the woods and fields,—lumbermen, engineers, sheep herders, campers, etc.,—are more liable to contract infection, although others may be infected from ticks brought to them on live stock. The disease is therefore a rural rather than an urban disease.

Life History and Habits of Dermacentor andersoni.—(See page 193.)

Recognition of the Disease.—The onset of the disease is similar to other acute eruptive febrile diseases, the symptoms varying in degree. There are chills or chilly sensations, severe headache and pains in other parts of the body, flushed face and injected and yellowish conjunctivae. Epistaxis is common. A macular roseolar eruption may appear on the face, neck and upper part of the thorax as early as the second day, but the characteristic petechial eruption appears about the third or fourth day on the forehead, wrists and ankles, spreading to the arms, legs and trunk. This petechial eruption may become purpuric in character. Gangrene of the ears, fingers, toes, scrotum or penis may occur. Leucocytosis is present. Albumin and casts are found in the urine in about 50% of the cases. Delirium is commonly present although the mind may remain clear

throughout the disease. The temperature rises rapidly to a moderate height where it remains for a week or ten days and then drops by lysis. The eruption may at times be seen on the palms of the hands and the soles of the feet. Jaundice is common. The case fatality rates vary according to locality from 4 to 75%; in Idaho 4%.

Clinically the disease resembles typhus fever very closely but cross immunization experiments have shown the two diseases to be distinct.

Methods of Control.—Prevention lies in reducing the number of ticks to a safe minimum. Burning over infested areas has been suggested, thus destroying ticks and preventing the development of the eggs.

Domestic animals should be dipped.

Sheep grazing should be practiced extensively over tick infested areas. This is probably the most practical method. Ticks soon die in the wool of sheep, for they find it difficult to move in the thick wool, becoming entangled in the hairs they cannot feed and they starve. Also the lanolin plugs their breathing spiracles. Copulation does not take place.

It has also been suggested that wild animals, especially the small rodents be destroyed. This is a difficult and expensive matter to accomplish.

Dipping Solution for Cattle.

Sodium carbonate, pounds	24
Arsenious Oxide (As_2O_3), pounds	8
Pine tar, gallons	2
Water to make gallons	500

A stock solution may be made by dissolving the soda in 25 gallons of water, adding the arsenic and boiling until combined. When cooled to 140°F. add the pine tar slowly while stirring. This concentrated solution may be diluted in the dipping vat when required for use. To be efficacious the final solution must contain 0.2% of arsenious acid. In the above formula it is therefore better to use pure arsenious acid or a somewhat greater quantity of the commercial form.

Tourists should be careful in camping where infected ticks are known to be common.

CHAPTER XXXVII

TSUTSUGAMUSHI FEVER

(Japanese River Fever)

Causative Agent. Unknown.

Methods of Transmission. The disease follows the bite of an infected mite (*Trombicula akamushi*) in its larval stage.

Source of Infection. How the mite becomes infected is unknown. The virus circulates in the blood of the patient and this blood when inoculated into monkeys and small rodents produces the disease in these animals. Rodents trapped in the locality and from which infected mites may be taken do not seem to be affected with the disease, although it is possible that they may act as reservoirs of infection.

Period of Incubation. From four to ten days.

Epidemiology. The disease is limited to the immediate vicinity of one of the rivers on the Island of Nippon, Japan, which overflows its banks inundating the adjacent land during periods of flood. This occurs about the month of June, the disease following in July or August among those who have worked the ground after the floods have subsided. The disease is said to occur also in Formosa.

The life history of the Kedani mite does not differ materially from other mites. The larva is very small and bright red or orange in color. The nymphal and adult forms do not bite but live on vegetable juices. Blood is obtained by the larvae usually from the small rodents of the locality especially the field mouse (*Arvicola hatanedzumi*) on which they congregate about the ears. The larva develops into an octopod nymph which after one or perhaps more moults becomes the fully formed acarine, which may be found under fallen leaves or decayed vegetable matter in the inundated area.

The infection is carried over from the larval stage to the nymphs and adults but as they do not bite they are not dangerous to man.

The disease does not develop after the bite of similar mites in other localities nor are all mites infective in the infected locality.

Recognition of the Disease. The prodromal symptoms are headache, malaise and anorexia. The onset begins with a chill

followed by a rise in temperature which in 4 or 5 days may be very high reaching 105 degrees F. The pulse is only moderately accelerated. Cough is present. In about seven days after the fever begins a rash appears first on the face and then extending to the trunk and extremities. The rash, at first large red blotches, may become papular— never petechial—and begins to disappear during the second week when the temperature also begins to drop. Examination of the body will disclose a more or less boil-like swelling which sloughs at the centre leaving an ulcer. This represents the site of the bite. The glands draining the bitten area are somewhat swollen and tender. Leucopenia is present and the spleen is usually enlarged.

Methods of Control.—Avoid the infested locality during the season of prevalence of the mite.

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